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ABSTRACT

Title of Dissertation: The Economics of Industrial Preparedness Planning and Raw Materials Stockpiling

William Scott Stambaugh, Doctor of Philosophy, 1982

Dissertation directed by: Dr. Mancur Olson Jr.
Professor, Department of Economics

An economy's reaction to a war is an important economic subject which has been relatively neglected in recent years. Such inquiry is the necessary basis of Industrial Preparedness Planning (IPP) and raw materials stockpiling by the Federal government. Some relatively sophisticated economic analysis techniques are used in present United States IPP and stockpiling but they have significant deficiencies. The most serious is the failure to consider the effects of substitution in a comprehensive way. This study hypothesizes that substitution could obviate the need for formal IPP and stockpiling of the type now practiced. To test this hypothesis, input-output, a major conventional tool of preparedness planning was exercised for a circumstance more likely to surface wartime stresses than government applications do. This approach identifies sectors experiencing large direct and indirect increases in demand, particularly in defense demand. These sectors are likely sources of high wartime stress. The study then focuses upon the substitution opportunities and the speed of substitution possible within a group of these sectors, the one which produces aircraft. The examination reveals that at virtually every turn substitutions can yield substantially more production in much less time than the con-

ventional wisdom maintains. This finding for a product with particularly great division of labor and of high military value strongly supports the hypothesis.

It becomes clear that standard economic analysis tools are not very satisfactory for preparedness planning because they lack explicit attention to time. This is importantly buttressed by the record of World War II which reveals much faster and greater production capability than then believed possible. To harness such potential now, planning must incorporate factors not included in its underlying economic analysis. One factor posited is that defense goods are two dimensional, one, the good's usual characteristics, and the other, time-of-availability. Time-of-availability is seen as potentially driven by preparedness actions to help insure the time needed to substitute away from shortages which might lead to strategic failure. The analysis also needs a behavorial input to make it relevant to the greatly changed circumstances of a war.

Study of motivational factors and time-to-availability is limited by the data presently collected and the possibility of rapid changes in production techniques. Without addressing these, it is likely that preparedness planning will continue to be substantially deficient. The study concludes that preparedness planning should be focused upon ensuring the adaptive efficiency to prevent strategic failure without maintaining large federal stockpiles.

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THE ECONOMICS OF INDUSTRIAL PREPAREDNESS PLANNING AND RAW MATERIALS STOCKPILING

by

William Scott Stambaugh

Dissertation submitted to the Faculty of the Graduate School
of the University of Maryland in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
1982

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I. INTRODUCTION

This chapter provides a short background to establish the relevance and importance of the subject. The hypothesis to be examined is then presented followed by the method of its testing and a plan of the work.

Industrial Preparedness Planning (IPP) and raw materials stockpiling are federal government activities aimed at increasing the resiliency of the nation to shock, particularly the shock of a large war. These subjects are regularly addressed using both partial and general equilibrium analysis. However, analysis of the process of change in equilibria is needed to avoid large peacetime preparedness expenses. This study provides a framework for a new approach to preparedness planning based on tracing chains of resource substitutions from pre-war to wartime conditions.

The ability of a nation to defend itself depends importantly upon its productive capacity. With a war deterrence strategy, peacetime forces-in-being may be a sufficient consideration for a national defense planner. However, if deterrence fails, or if the ability of a nation to reinforce and sustain pre-war forces is an essential element in deterrence,[1] then the ability to mobilize the economy is important to defense planning. During the last few years there has been growing interest in the mobilization ability of the United States as a major non-nuclear war is considered more plausible than before. Two recent Secretaries of Defense have reflected this:

"But nuclear parity has forced all of us to recognize that the use of the more traditional types of force by our adversaries may seem to them less risky than formerly." and "...the potential destructiveness of new weapons leads reasonable people to recognize that nuclear forces are instruments of last resort, and that the more traditional conventional capabilities remain of fundamental importance in today's world. In essence, we are seeing a revival in the importance of non-nuclear military capabilities."[2]

This perception is not shared by all; some see conventional warfare as continuing to become less probable. Nevertheless, some of those with the latter view also see a need for more refined economic analysis to support policy on preparedness aid to industry.[3]

Even if the probability of a conventional war were small and not increasing, its consequences are potentially so large that study is justified. While the existence of nuclear weapons on both sides might reduce the probability of conventional war or limit its extent "...we have yet no warrant for believing it would lower the possibility of conventional war to zero."[4] Moreover, during a period with great technological change and a multiplicity of weapons, preparation for war must be flexible and multifaceted.

During the 1930s most Americans believed that there were specific plans to convert the economy to war production, e.g., the M-Day Plan. They supposed that thorough data about military and civilian needs during wartime had been collected.[5] World War II showed how incorrect this belief was. In the 1970s it appears that some in our society possess the same belief that predominated in the 1930s. This is spurred by the existence of the Federal Preparedness Agency (FPA),

the Office of Industrial Mobilization, the Office of Civil Defense and other government offices largely created during World War II, and by the development of plans by the military services such as the Air Force's War and Mobilization Plan. Over the years these governmental offices have not been vigorously sustained and academic interest in their economic and industrial underpinnings has waned. Meanwhile, the complexity of the economy has increased secularly, and the manpower, data bases, and expertise needed to transform the United States quickly into a wartime economy has changed. During these years the prevailing view in national defense circles has been that the United States will prevail in any likely scenario by means other than producing larger quantities of weapons than an adversary. This is consistent with historic United States inter-war practice; attention to industrial preparedness and raw materials has never been a major national defense priority except during a conflict or when one appears inevitable. This approach is supported by a belief that economies are inherently very flexible, and that many substitutes always exist and other can be discovered and used quickly. In this view, present planning and expenditures, particularly regarding raw materials, are excessive. Consistent with this view, efforts have been made in recent years to cut present stockpiles.[6]

The experience of Germany during World War II further supports this view. Germany demonstrated substantially more adaptability than was believed possible.

When there are many substitution possibilities and substantial technological change, input-output coefficients are always open to question. In addition, in these circumstances, coefficients are more likely to be seen as affected by commercial custom and habitual practice and thus presage even more instability in wartime. In its core this view finds no need for analysis of stockpile requirements or for IPP because factors are so quickly transferred to alternative uses in wartime that pre-war plans are useless.

There is a second view of the condition of the United States industrial base. For example see the judgment of a recent Chairman of the Joint Chiefs of Staff:

> "In summary, I remain uneasy about the ability of our industrial base to respond rapidly to the military requirements which would evolve from a major conflict.........A strong industrial base is a key element in our military might."[7]

Those with this view believe that economic activity, particularly industrial production, is inherently not very adaptable i.e., that the world is essentially characterized by fixed coefficients. Since World War II this approach has been dominant within the parts of the national defense establishment which do raw materials stockpiling and IPP. As a result, these activities have been out of harmony with the thinking of top defense and national security planners and have received small budgets.

This second view supports analysis of the economy using input-output and essentially static capacity measures. In this approach, technological relationship is the key deter-

minant of input-output coefficients and secular change is presumed slow. Consistent with this view, the 1958 input-output coefficients were still in use in the mid-1970s in Federal stockpile requirements calculations and substitution was considered only in a minor way. In addition, there were few vertical slice analyses of specific industries' defense production potential. Stable relationships lead to stability in needed stockpile holdings and in related governmental administrative actions.

Although these viewpoints regarding the adaptability of the economy are diametrically opposed, neither generates much impetus for detailed analysis of defense preparedness. In the fixed coefficient view there is little substitutability to discover and in the other there is so much substitutability that study is not needed. These opposing judgments mask the need for systematic and detailed analysis of the United States economy to determine if relevant substitution possibilities do indeed exist for vital defense goods. This study is such an effort.

The specific hypothesis to be investigated is that sufficient opportunities for timely substitution in defense production exist to obviate the need for present Federal government raw materials stockpiling and IPP programs.*

* Hereafter the word stockpiling will be used to denote raw materials stockpiling and the term preparedness planning will be used to denote both raw materials stockpiling and IPP.

To test this hypothesis it is necessary to expose structural elements of the economy that provide defense goods, along with alternative methods of achieving the same military end through substitution. This approach begins with the exercise of a conventional tool of economic analysis regularly used in analyzing preparedness, an input-output model. This tool satisfies the need to cover the breadth of the economy while exploring its structure. The model is used to identify some of the most highly stressed sectors in an illustrative, generalized war scenario. One of these sectors is then examined in considerable detail as a test of the hypothesis. The uses of this sector's products and of inputs and alternative inputs to the sector are probed. If the hypothesis is not disproved for this "difficult" sector a strong case is made for application of this approach to other sectors. Policy changes then would be indicated. Of course, even if enough timely substitution possibilities are found the potential wartime loss could be extremely high if a larger stress occurred, so the nation might still prefer to maintain these programs. Even in this event, this type of inquiry clarifies the risk averted with these expenditures. The scenario used here is more than twice as large as the conventional war now addressed in preparedness planning and thus accepts less risk. Consequently, results should be applicable to a wide range of crises. The nuclear war case is not considered here; it is a substantially larger and different type of stress. A model appropriate to study of national recovery from a nuclear war was developed by

Marshall Wood in the early 1960s.[8] Some elements of that model are applicable to this conventional war case. See the discussion below.

The responsiveness of the economy is a question of increasing concern to policymakers because the United States and NATO allies are seen by many as inferior to the Warsaw Pact in standing conventional forces.[8] Notwithstanding this trend, the United States has done little to prepare for a rapid, massive, and sustained conventional force mobilization. Some stockpiles, essentially created during World War II and the Korean War, are maintained and limited money is spent on Industrial Preparedness Measures (IPM). Little has been done because of constrained budgets, uncertainty in threat assessment, and judgment differences on how long a war should be sustainable. This latter point has been influenced significantly by the record of the 1973 Yom Kippur War when much higher than anticipated attrition and supply expenditure rates were experienced. Some believe that this indicates that a war in Europe would be short because opposing forces would be lost rapidly; therefore only highly ready forces should be maintained to win a short war. Others see the need for forces and inventories of supplies to sustain long after a relatively short initial surge. Some policy makers appear to accept the short war view because prospective peacetime budgets cannot make planning for a long war effective. Thus, if the hypothesis of this study is not disproved more sustainability may be planned because it would cost less than had been supposed.

The argument in recent years between the advocates of increased size and readiness of standing forces and those of force sustainability is much like that in Germany in the early 1930s when the military wanted to arm the nation in depth so as to sustain in battle against prospective combatants versus Hitler, who favored "armament in width" which would provide a military capacity quickly in a blitzkrieg.[9]

Those who favor a highly responsive standing force lack a satisfactory answer about the consequences if a war is not won quickly. Usually, the answers are that there would be resort to nuclear weapons or that a political accommodation would be necessary. Both implications are quite pessimistic. The alternative is systematic analysis followed by action to achieve sustainability. Assuredly, care is necessary to preclude a binary division -- spend all on sustainability or all on readiness. Determining the balance is a classic economic analysis case.

This paper accepts part of the position of both the readiness and the sustainability views. A war which consumes supplies at a rapid rate but does not quickly reach a conclusion is a real possibility for which both readiness and sustainability are needed. In a sense, this view is the worst of both worlds, one in which initial stresses are high and in which they must be sustained, possibly during substantial disruption of supply from overseas. The real issue is the adaptability of the United States economy in a stress

situation. The stress analyzed could spring from other roots, e.g., a worldwide drought or destruction of Mid-East energy sources.

This inquiry into the availability of timely substitutes is pursued within a context of two other major themes of importance to modern economists. Both are examined at some length because they are particularly relevant to this issue and because neither has been found to be addressed significantly by those developing preparedness policy. Economists also have tended to neglect both, particularly in studying national economic stresses. The first is the motivational underpinning of economic activity and of its treatment in conventional economic theory. The second is the nation's entry into a period which has potential for very rapid technological change, a period which might be termed "an industrial revolution." As the possibilities for substitution increase, preparedness actions which are not based upon analysis of these factors run the risk of being excessively expensive and possibly ineffective as well.

The plan of the work is as follows. Chapter II develops the central importance of time in addressing the hypothesis. Preparedness spending is seen as buying wartime time to prevent strategic collapse of the economy. The chapter builds upon recent work in consumption theory which adds a second dimension to conventional consumption goods, the time spent in the process of consumption. This study adds a different time dimension, time-to-availability for consumption. At its

core this is the production thruput time of defense goods to be produced during the mobilization. Chapter III identifies potential high stress sectors, using the INFORUM model. One of these sectors which produces important defense goods is then selected for more detailed subsectorial analysis as a case study in support of the hypothesis. Chapter IV uses both INFORUM and the non-INFORUM data to assess the possibility of satisfying increased sectorial and subsectorial wartime demand through series of substitutions. Inputs to production of facilities, equipment, components materials, fuels, and labor are examined for bottlenecks for which there are no possibilities for timely substitution to alleviate the shortage. Chapter V establishes that there are biases in data and conventional models which indicate that INFORUM calculations are likely to understate wartime production potential. Problems inherent in input-output analysis, capacity measurement, and the lack in modeling of pertinent underlying wartime behavioral assumptions are examined. Chapter VI posits that prospective technological change will tend to reduce the need for stockpiling and IPP. Many more substitution possibilities will be created and present substitution possibilities will change. Chapter VII is findings and implications relative to the hypothesis of Chapter I.

II. THE TIME DIMENSION IN IPP AND STOCKPILING

The beginning of a war creates a classic economic disequilibrium, one that Marshall specifically excluded from his consideration of markets.[1] This study addresses this gap in traditional neoclassical economics; IPP and stockpiling are pursued by nations specifically to bridge this disequilibrium situation. In a normative sense all prewar spending on IPP and stockpiling are to buy time in wartime. This chapter's goal is to answer the questions of why, and in what ways, consideration of time is important in determining if IPP and stockpiling programs are necessary. The chapter further posits that a different analytic core for preparedness planning which includes time will yield a more effective and efficient means for bridging disequilibria in times of economic stress.

Present preparedness planning is grounded upon economic theory and the experience of World War II (some relevant historical background is in the Appendix). As the economy has become more complex the level of effort and economic tools employed have changed slowly. While economic theory and World War II experience are both relevant to preparedness planning their application needs to be reviewed to incorporate new insights and to revalidate older findings. The way the time dimension was considered during the 1970s indicates that little of this has occurred.

The lack of attention by economists to disequilibrium adjustment and the time necessary for it is not only traceable to Marshall. For example, Walras' timeless adjustmen

assumption is widely adopted. Likewise, Edgeworth did not even note that a period for reaction is a consideration.[2] Today there is widespread concern that dichotomous events, even in peacetime, have increasingly invalidated economists' policy prescriptions. This is reflected in calls for less deterministic theory and, alternatively, for more deterministic theory with more factors included.[3] A war clearly calls for at least a significantly refined understanding of conventional theory if preparedness planners are to adopt more than a fixed coefficient view (and attendant large stockpile requirements).

There is evidence within some defense activities that this fixed coefficient view is spreading and that the industrial base is becoming less flexible. Klein sees military organizations and industrialists as increasingly intolerant of uncertainty and unwilling to live with ambiguity:

> "During World War II, the Office of Scientific Research and Development was famous for sponsoring a wide diversity of approaches. But during peacetime, research and development organizations such as the Atomic Energy Commission or the National Science Foundation have been famous for concentrating upon a narrow menu of alternatives, because such a strategy minimizes bureaucratic risk."[4]

This mindset, in the face of the conviction since World War II to defend the nation using more capable weapons than the enemy,[5] creates potential for a technological Maginot Line. Thus, if defense industry narrows the technological choice to highly specialized materials and/or manufacturing processes an enemy might be able to bypass preferred United States defenses and force use of less capable systems which

can be produced in time. Avoiding such a condition can require very large standing forces and/or high peacetime production rates.

An alternative is to take deliberate action to insure that the flexibility for timely response is inherent in the supporting industrial base. Given the size of the United States economy and the small proportion in peacetime defense production, one way to do this is to plan to quickly involve non-defense industries in defense production. Defense spending is between five and six percent of GNP and less than half of this is for materiel procurement, so there is much additional potential in the economy. This potential has changed dramatically as the numbers of military items bought has secularly declined (see Table 1). This, coupled with a perceived trend requiring more specialized materials, components, industrial equipment and labor in production has left increasing potential untapped.

TABLE 1. YEARLY ACQUISITION OF ILLUSTRATIVE MILITARY ITEMS

ITEM	1944	1954	1964	1974
Aircraft*	96,318	5,429	2,439	1,110
Combatant Ships	410	27	8	5
Submarines	121	0	16	1
Tanks	17,565	3,708	625	457

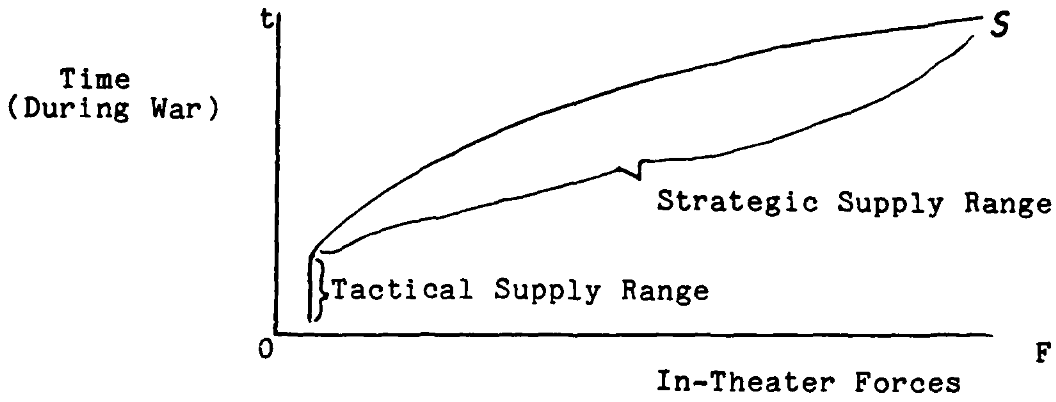
*Includes helicopters and foreign sales as appropriate.
Sources: U.S. War Production Board, Official Munitions Production of the United States, p. 339, 340, 344, 407, 408. Gansler, Jacques, Industrial Base Briefing, Washington, 1977. Aerospace Industries Association of America, Aerospace Facts and Figures 1978/79, p. 36.

With an economy larger than that of the Soviet Union, the United States and allies can risk maintaining smaller standing forces if there is assurance that the economy can be reoriented to defense in time to prevent strategic failure. Thus, strategic failure has a connotation of being longer run and more national in scope than tactical failure. With strategic failure a nation loses control of its destiny and further efforts cannot reverse the course of events. A strategic supply shortage is very serious in contrast to shortages in tactical situations when "....no amount of extra supplies can be substituted for the missing good...."[6]

The distinction between strategic and tactical supply is useful in addressing the need for IPP and stockpiling. Preparedness spending is necessary <u>only</u> to prevent strategic failure; tactical failure is important only in that a series of tactical failures may portend strategic failure. A tactical situation is analogous to a Marshallian market period and a strategic situation encompasses Marshallian long and short runs. Figure 1 helps describe the contrast. Here time is used in the place of price on a conventional supply curve. This reflects that time is the scarce resource while the money price of time is undergoing rapid change or is fixed by government. As drawn, there is an implication that most situations are strategic supply cases in which strategic failure will not occur. As time passes, forces are transported to the theater, production occurs, and substitution within the structure of supply proceeds. Additionally, the locus and shape of the curve changes as forces are destroyed

or productivity changes.

FIGURE 1. TACTICAL/STRATEGIC SUPPLY CURVE



Tactical failure never affects the entire national effort at one time although it can affect any element, i.e., it might occur anywhere in the production sequence from raw materials to the battlefield. Strategic failure, however, implies certain collapse of the entire effort.

This curve helps portray a useful concept for an economy adjusting to stress, that of time elasticity. Time elasticity, E_t, is defined as $\frac{\Delta F}{F} \div \frac{\Delta t}{t}$ where F = in-theater forces and t = the elapsed time during the wartime supply process. This is a measure of the adaptability inherent in the economy in support of the war effort. The question of whether or not the trend has been toward a technological Maginot Line can be conceptualized using this figure. With more specialized defense production and lower time elasticity the prospect of a discontinuity in the strategic supply range increases.

Since the pre-World War II period many changes have affected the shape and locus of this curve. Some changes tend

to increase adaptive efficiency, others decrease it. The increasing specialization of civilian production and the adoption of myriad production standards have probably reduced its time elasticity. While this has occurred the locus has shifted to the right because of larger peacetime forces and overseas deployments. Because of larger prewar forces a particular percentage increase in forces now is more difficult to attain in a given time because it is a larger absolute increase. Moreover, as force size increases, diminishing returns in their development and transportation might be expected. However, secularly the capability to transport forces quickly from the United States to forward areas is greater - a factor that tends to increase time elasticity. Likewise, today there is a greater variety of military goods available to perform essential military tasks. This increases the range of possible substitutions and the elasticity of the curve. On the other hand, the trend (reflected on Table 1) toward producing smaller quantities of many military items tends to reduce elasticity. This results from smaller inventories of goods-in-process for many military good and the well known modern industrial fact that for major defense weapons the rate of production can be accelerated easier from a large production base than from a small production base. This implies that these goods tend to be specialized and to be produced in quantities at which increasing returns occur.

Now let us examine the ways in which the time dimension impacts IPP and stockpiling. First, is the war's duration. How long must operations be sustained to assure no strategic

failure? The impact of this planning parameter was highlighted by the 1973 changes in stockpile objectives for raw materials. When the planning horizon was reduced from three years to one year, objectives which had been valued at about $4.1B were reduced by $1.5B.[7] This is with a war scenario somewhat different from that used in this study; here the impact of a two year reduction in duration would be significantly larger because of a larger force size. This stockpile estimate depends, of course, on the acceptance of the fixed coefficient viewpoint as used by the FPA. In addition, there would be large industrial impacts from differences in expected war duration. If the production rate of war equipment and munitions is to be sustained, rather than just briefly attain a high level, the overall production effort must provide the additional components, equipment, tools, etc., for the next period.

A second aspect of time which impacts mobilization potential is the year of the war's occurrence. Where the economy is operating relative to raw material, plant, machinery, and labor capacity is important. Clearly the ability to increase production rapidly is greater when more unused capacity is available. Workers with current job skills and the necessary complement of capital can quickly be put to work. On the other hand at the peak of a boom, additional rapid production increases are harder to achieve, although firms may have more efforts underway to increase capacity. Cyclical capacity is examined more thoroughly in Chapter V. Additionally, the effects of prospective longer

run technological change on wartime production potential are addressed in Chapter VI.

The third consideration of time to be explored when trying to produce additional weapons within a specified period, is lead time, or essentially production thruput time. This should be the main focus of preparedness study. Unfortunately it has not been. There has been great difficulty in linking IPP and stockpiling actions to specific war fighting, or deterrence capability. For example:

> "An effort to define such costs and weigh these against the intangible benefits (emphasis added) of an improved mobilization capability is recommended....Some officials familiar with the preparedness system also feel concern over divisions of responsibility, possible gaps between agencies, and a lack of full coordination in the system as it is today, essentially untested for twenty years."[8]

The lack of focus on production thruput time for specific, high priority defense goods can be corrected by the use of a construct increasingly used in economics, multidimensional notional goods. Becker has postulated composite utility producing goods composed of standard products and a time characteristic and provided an improved explanation of consumer behavior.[9] This is particularly appropriate for preparedness planning. Not only must defense forces have the necessary performance characteristics but they must be available in a timely way to achieve utility.

This importance of time is now formally recognized in peacetime weapons acquisition since continuing attention is given to tradeoffs between performance, dollar cost, and

schedule. Even here, schedule regularly takes a poor third place to system performance and lower dollar cost. Furthermore, the interpretation of schedule used is not thruput time -- instead it usually is time to initial operating capability. The relative priority of these three factors would shift abruptly in wartime, particularly in a large conventional force mobilization. In this event there generally will not be time to develop new weapons so those of acceptable performance which already are developed will have increased production. Additionally, there will be little money constraint, although there may be materials, labor, or component shortages.

The various aspects of time interact in a mobilization situation. Cyclical and secular parameters affect the thruput achievable for incremental units of production, as does the choice of planning duration. The thruput achieved is a determinant of the actual war duration which can be sustained, i.e., whether strategic failure can be avoided. All of the characteristics together determine the ability to maintain intense activity in combat, sustainability.

Adapting Becker's approach to war goods production in a more formal way is done in the implicit equations below. The national defense utility function which is to be maximized is shown in equation (1).

(1) $U = U(F, T, S)$

Where:

F = wartime forces in-theater (expressed as a number of fully trained military units, e.g., combat ready fighter

aircraft squadrons). An increase in F would yield increased utility as citizens then feel more secure.

T = the timeliness of ready forces arriving in the battle theater; it is measured in time units. dU/dT is negative because earlier arrival of forces increases the probability that allied territory is not overrun and thus helps defend the United States further from our borders.

S = combat sustainability. This is a measure of the ability of pre-war units to maintain combat operations at pre-war planned activity levels over time. Thus, each committed squadron might be expected to fly fifty sorties of a particular type each day. The time over which this could be continued is the unit's sustainability. dU/dS is positive - if activity is maintained longer than enemy forces can sustain, victory follows.

The interest here is primarily with sustainability; those who develop combat forces establish F; and mobility planners are concerned with T. Sustainability, in turn, is created by the combination of the inputs (in stock terms) of materials (M), labor (L), equipment (E), the original force (F), and production thruput time (t).[10] Spending on IPP and stockpiling affect the underlying determinants of the labor, materials, and equipment used to produce sustainability. The implicit relationship in producing sustainability is:

(2) S = S (M, L, F, E, t) where dS/dM, dS/dL, and dS/dE are positive and dS/dF and dS/dt are negative.

Increased stocks of materials, labor, and equipment provide increased supplies that are worn out or expended in

military operations. Sustaining F for a longer time becomes more difficult the larger F is. Also, the more resources that are used to sustain existing forces the more difficult it is to expand forces. At some point it may be necessary to increase F as combat is sustained. This depends on the enemy's ability to increase force capability. Likewise, after some elapsed duration, it becomes easier to produce, and employ, additional forces <u>because</u> more wartime time has been input. This is pictorially depicted on Figure 2 below.

To insure increased sustainability, shorter thruput time, t, is required. Thus, the tactical supply range (Figure 1) decreases and strategic failure is less likely.

If production relationships are completely fixed coefficient and excess capacity does not exist, then pre-war actions must be taken to increase the amount of wartime inputs. Doing such things as storing upgraded materials, developing equipment with faster operating rates, or training more skilled labor could fall in the category of preparedness planning. All of these are not considered at present; labor is not explicitly trained nor faster machines developed as part of IPP.

If the easy substitution view discussed in Chapter I is accepted, time and other factors in production are substitutable. Preparedness planning then should be a search for these relationships until some substitutions are found to be too slow, then it should facilitate these conversions. Wartime time beyond the planning horizon can only be a substitute for other factors if wartime requirements change.

In addition to (2) and the planning horizon, To, the national defense utility function is subject to constraints on F,M,L, and E:

(3) $F=F\ (Fo,\ t)$, with $dF/dt < o$.

(4) $M=M\ (Mo,\ MM,\ E,\ L,\ t)$, with dM/dE and $dM/dL > o$, $dM/dt < o$.

(5) $L=L\ (Lo,\ t)$, with $dL/dt < o$.

(6) $E=E\ (Eo,\ Mo,\ L,\ t)$, with $dE/dL > o$, $dE/dt < o$.

(7) $t < To$ is necessary if production is to be helpful within the planning horizon.

Where Mo, Lo, Fo, and Eo are stocks at the beginning of the production period and MM is the stock of less processed materials available during the production thruput period, t. The amount of Eo, Lo, MM, and Mo available could be a function of pre-war preparedness planning actions, in addition to existing merely as a result of peacetime production. Also note that the increased availability of one input, say equipment, can yield an earlier requirement for another input such as materials. Thus, IPP and stockpiling can be complementary actions.

The task is the maximization of the national defense utility function (1), as interpreted by the President or the National Security Council, subject to the sustainability production function, S, and the constraints (3)-(7). The optimal solution depends upon the specific form of these functions. Detailed time accounting along the vertical slice of the production process is necessary before a determinant solution is attainable. Moreover, unless fixed proportions

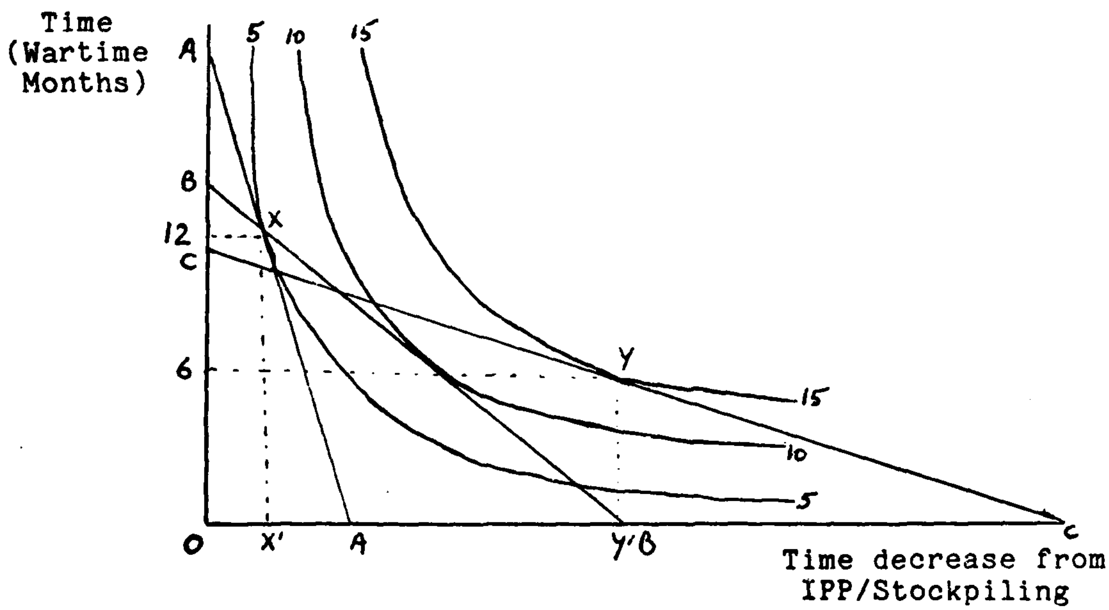
are used the solution is mathematically complex. Later chapters in this study are searches for substituion possibilities to determined which approach is most applicable.

The variables needed by policy makers to attempt to maximize national utility for defense are the production thruput times for each vital type of material, equipment, and labor. With these, the availability of additional forces and force sustainability can be derived. In recent years the policy-making process has been relatively insensitive to these time constraints. In fact, there appears to be significant gaps in the gathering of basic inventory data for civilian use of specific types of materials and equipment with possible defense applications. Additionally, industrial labor has not been well tracked. These factors accentuate the importance of formally addressing production thruput time.

Note that neither money prices nor income enter any of the constraints; this is because in the essentially command economy imposed under the provisions of the Defense Production Act there is government allocation of resources for defense priority items and comprehensive wage and price controls. War mobilization is a case in which the inclusion of prices, even historically precise ones, in an interindustry model will not lead to the optimum solution. With money prices essentially inoperative, the relevant constraints include materials, labor, equipment, and time. In fact, after a weapons system is selected for production analysis,

the focus should be particularly on costing in time units because time is likely to be the most scarce wartime resource. In effect, the time dimension of the composite Becker good is primary. The only other pertinent cost would be that of some material, machine, or labor skill found to be in short supply. This, in turn, would then be examined on the basis of the wartime time necessary to satisfy this shortage, either by production or substitution. If this can not be done without preparedness planning, then stockpiling and/or an IPM that promotes a different process or material to perform the desired function should be instituted. The conceptual approach for such production analysis is depicted in Figure 2.

FIGURE 2. WARTIME INCREMENTAL PRODUCTION



The isoquants labeled 5, 10, and 15 depict incremental levels of output per month produced by inputs of pre-war funds and of the use of time during wartime. The isoquant of planning interest and the relevant time horizon would be selected by the national command authority. Note that if much time is judged likely to be available in wartime little or no pre-war preparedness spending may be needed. In Figure 2 an opportunity set of wartime time and decreased thruput time gained from increased peacetime preparedness spending is portrayed (A-A). This depiction acknowledges the interrelatedness of these factors in increasing wartime forces in a timely way. A straight line is assumed for illustrative purposes only. A-A is an isotime line analogous to an isocost line in conventional production theory. In effect, here alternative inputs are used in producing a good but both inputs are priced in time units rather than money. This is consistent with wartime price and wage controls and the fact that time is the scarce resource.

In the case shown with A-A, a monthly increment of production of five aircraft could be attained within twelve months. The subpoint, X', indicates the needed preparedness spending level (alternatively, the decrease in thruput time from IPP) for this twelve-month delivery. If delivery within six months were desired, IPP spending would have to be increased to reduce the slope of the isotime line to that of BB. In this hypothetical figure a wartime production increment of fifteen F-16s per month could be attained in six months with an preparedness spending level consistent with Y'

i.e., using the isotime line depicted by CC.

Implicit in this construct is much suboptimizing both within IPP and stockpile spending and between preparedness spending and the existing capacity of the firms involved in F-16 production. Ideally, any preparedness spending is used to achieve a completely balanced mix of factors for the level of production and time horizon desired.

When this trade-off is considered with an explicit time dimension, it is clear that the balancing of capacity is difficult because the ability to produce the various inputs are likely to expand at different rates, particularly during the early wartime months. Moreover, a production base optimized for maximum production after three years of war is likely quite different from one optimized for a one year war. Both are likely to be far superior to the present base which is haphazardly structured for peacetime production based on available annual Budgets.

There are hazards in analyzing one industry or part of an industry in isolation. Unless all firms which provide inputs to and make demands upon the industry are addressed the situation becomes one of acquiring resources at the expense of related industries. This is why consideration of indirect effects and the speed of substitution is so important. If other factors can be used in the defense industry, or if industries competing with defense industry for a factor can have their functions easily performed in an alternative way, then partial equilibrium analysis causes no problem. The amount of competition between defense producers for

available inputs is explored in Chapter III.

At present, only one point on each isoquant is derivable, the combination of current F-16 preparedness spending and the estimated resulting wartime production schedule. Other points could be obtained by detailed critical path analysis. Then IPMs that shorten the critical path can be purchased. However, after a constraint is removed the critical path itself may change. The critical path analysis performed by General Dynamics in calculating F-16 assembly and delivery schedules indicates that sustainable production of five additional aircraft per month within a year might be possible, while fifteen per month is not.[12] In deriving more points on the isoquants a complete vertical slice from finished goods back to raw materials must be considered. However, the further the analysis proceeds from the final product the more fungible is the input. For example, raw materials are much more widely and quickly substitutable in production than specialized components and tools, and both of these are generally more substitutable than final products.

The first step in assessing the need for stockpiling for a weapons system is to develop a complete bill of materials and to determine which are on the critical path. Then, supply sources from commercial inventories and secure production must be found. These sources must be ones that will not be allocated, even by government under severe pressure, to other uses in wartime. If this can not be assured, stockpiling may be needed.

Because production thruput time begins with the requisite raw materials there often is a supposition that if specific raw materials are not available, then no production can occur. The valuelessness of this physiocratic view has been assessed elsewhere.[13] Raw materials are generally more substitutable between uses than goods-in-process or finished products. This can be an advantage in planning for situations of uncertainty. Additionally, raw materials provide advantages over processed goods in storage, obsolescence, procurement, and capital carrying costs. Nevertheless, raw materials are at a great disadvantage in preparedness planning when the time of availability of weapons is a central planning parameter. Each stage of production costs time. Consequently, raw materials are least responsive to specific emergency needs because they have more stages of production to traverse. The underlying central economic truth is that no factor of production is more important than any other. The timeliness of all must be equally weighted in preparedness planning. However, this has not been true in the past. For example, the same attention has not been paid to labor availability as to raw materials, and labor is generally likely to be even more substitutable than materials.

Ceteris Paribus, as the planning horizon is shortened more spending on both IPP and stockpiling is likely to be needed. Less time is available for substitution and therefore they become more complementary. This fact does not seem to be generally recognized, probably because institutional responsibility for them is diffused. This lack of synthesis

is not new, it traces at least to World War II.[14] Because coordination difficulties were severe then, when virtually everyone strongly supported rapid production, there must be inherent difficulties with the subject which cause confusion. One submits that an inadequate analytic basis, one not focused on time, has yielded a weak organizational structure for coordinating these efforts. In addition, administrative capability probably has deteriorated in recent years because the economy has not been stressed severely since World War II and most individuals with World War II experience now have departed government service.

The lack of a consistent time horizon for preparedness planning has yielded IPP using a three year period for aircraft, five years for shipbuilding and other periods for other force elements. Stockpile planners use three years, although this was changed to one year in 1973 and later changed back. In addition, elements of the DOD use various planning durations measured in weeks, or at most months. Time in adjusting to the disequilibrium circumstances of a war is not the focus of present preparedness planning, although it should be.

Defense production is particularly impacted by one other aspect of time, one that affects thruput, is sensitive to the planning horizon, and is influenced by cyclical and secular trends. The effect of the input of time in improving production techniques should be considered. It is well known that learning-by-doing is a major contributor to increasing product quality and reducing production cost. This learning

could also be focused upon reducing thruput time; people learn to build a product rapidly by trying to build it rapidly. This effect would be seen on the time variable in equations 2-6 above. It could revolutionize preparedness planning. Learning-by-doing regularly is assessed by industrial engineers using the concept of learning curves.* The concept was first developed in the aircraft industry during World War II and now is part of the pricing basis of much defense procurement, and particularly that of aircraft. The learning curve is much more important in determining average unit cost of military weapons than it is for most consumer or private sector investment goods because the number of units to be procured is typically fewer and the production process less mature. Therefore, while short run average cost curves can recognize changes in the capital/labor ratio and changes in the specific factor mix they shift rapidly in a war situation. As a result, learning curves which expressly recognize changes in knowledge can be even more useful. Usually learning curves are used in industries in which there is more than average technological change and in labor intensive manufacturing with a high proportion of assembly operations, such as airframe, machine tool, and electronics component production.[15]

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* Generally a learning curve means that as the quantity produced doubles, the cost per unit (usually expressed in direct manhours) decreases by a constant percentage (commonly 18-20 percent for military aircraft).

The capability to orchestrate the time phasing of the many inputs to production underlies the cost reductions achieved, and often is important throughout the production run of defense goods. As a weapon proceeds from development to production, managers and engineers define the product more precisely. Until this time it is impossible to anticipate all components, tools, types of labor, etc., necessary for production because development regularly uses "soft" tooling. The result is much wasted time early in the production run as labor, capital goods, and raw materials wait until undelivered inputs arrive or existing factors are modified. Some of this delay can be reduced by increased money expenditures. The trade-off is the cost of retaining already purchased, but idle, labor and capital versus the premium necessary for accelerated delivery of the item(s) missing.

Defense contractors in peacetime probably do not always act with a free market impetus towards saving time because much of the capital involved is not theirs. Government furnished components, plant, and equipment plus progress payments for inventory substantially reduce capital costs to them. Likewise, producers sometimes manipulate the indicated rate of learning to help maintain employment stability, and possibly to favorably affect subsequent contracting. This can be done by being selective in choosing the historical base, in classifying labor as direct or indirect, and in adjusting to changes in lot size, tooling, materials availability, and inflation.[16] This misuse undoubtedly bias s indicated thruput potential downward. Notwithstanding these

difficulties, learning curves are extremely valuable in assessing production potential of important defense goods.

The literature on learning curves has established that the rate of learning is not solely a result of additional units being produced; more learning occurs if the same number of units are produced in less time. This important industrial fact supports the view that peacetime productivity experience, capital/labor ratios, etc., will be invalid in wartime.

Therefore, in a period of great stress one should expect the production response to be faster than in peacetime both because peacetime data are biased toward indicating less capability and because learning-by-doing will occur faster. As a result, learning-by-doing seems particularly germane to wartime mobilization study and is strongly supportive of the hypothesis of this study. Surprisingly, the sizable learning curve literature does not appear to have been incorporated into economic inquiry on stress situations. It is a compelling argument for recognizing production time as an independent factor of production (as done in equations 2-6).

In this chapter we have discovered that consideration of time should be at the heart of determining the need for IPP and/or stockpiling. Pre-war resources for these programs are spent solely to buy time while the economy is reoriented to defense production. Being able to bridge the disequilibrium between peace and war without experiencing strategic failure is the essence of preparedness planning. This has not been the focus in recent years. Instead, preparedness planning

has been dominated by what Klein calls Bayesian middle-class rationality, the type of rationality embraced by Marshall and others in excluding dichotomous events and time for adjustment from economic inquiry. This approach has yielded a slow learning process and very gradual change within a semi-closed system.[18] Both the dynamics of initial adjustment to a war stress and the state of preparedness analysis dictate a broader and more vigorous approach - one Klein calls "happy warrior rationality."

In answering the question of how time affects preparedness planning and how a more effective and efficient analytic base for these activities can be approached a wide range of factors have surfaced. The possibility that a more inflexible industrial base has been inadvertantly created since the end of World War II was uncovered. A concept for analyzing flexibility, time elasticity, was then developed. Next, the chapter developed the ways that time has a major effect on IPP and stockpiling; war duration, cyclical and secular period of the war, and most importantly, production thruput time. The focus on thruput was then cast in terms of an adaptation to production of Becker's use of a two dimensional notional good with time one of the dimensions. Then, the constraints along vital defense goods' critical paths were seen as warranting inquiry in cases where thruput time was too long relative to the planning horizon. This understanding would serve as the baseline for assessing the possibility of substitution supplanting present stockpiling and IPP activities. An additional aspect of time that was presented that

should impact preparedness planning was that much learning occurs during production of defense goods. These goods often are technologically innovative and are produced in small quantities relative to typical consumer products. This yields a potential for large wartime reductions in production thruput time. In summary, time available to implement long sequences of substitution must be available if strategic failure is to be prevented without Federal stockpiling and/or IPP.

III. HIGH STRESS SECTOR IDENTIFICATION

This chapter delineates the inputs to, and results from, the University of Maryland input-output model, INFORUM, in identifying the major sectors of the economy which are highly stressed in an illustrative war scenario. Appendix B provides a brief development of the model and of how this model is used to calculate sectorial total outputs. This tool is used to discover which sectors are most likely to require preparedness planning. A related question which this chapter is to answer is what sector would be a demanding case study test of the hypothesis, i.e., to select a sector which requires a large increase in demand, is clearly important to wartime military activity, and in which it may be difficult to find sufficient substitution opportunities. The chapter is aimed further at identifying the most likely stressed input sectors and subsectors for the case study industry as well as the general disposition of that industry's output.

This model is similar to that used in government preparedness analysis. Its most important virtue is that it helps calculate indirect repercussions of changes in the level and structure of demand. Because any stress situation, such as a war, is highly unpredictable this type of model also allows examination of a variety of hypothetical scenarios in considerable detail. The energy crisis has prompted increased use of input-ouput analysis and significant strides in improving these models.[1]

The increased sophistication of an input-output model over the naive approach of only considering direct impacts of

an increase in defense demand is evident in the empirical work below. It also becomes clear throughout the study that work is needed to expand the capability of these models because the trend is toward an increased proportion of indirect effects. The proportion of a final product which originates in the final product industry, let alone in a particular plant, tends to decrease as the division of labor increases. The effects of this are not generally appreciated. While the number of sectors used in models have increased, little attention has been given to the cumulative effect of the added steps in production. This subsectorial proliferation makes detailed analysis of the industrial mobilization process more critical.

This study probes the sectorial and subsectorial detail of an industrial sector in which there is more than average division of labor. First, such a potential high stress sector must be identified. To do so, a difficult scenario is postulated and used as an input to INFORUM. This situation is not likely to actually occur. Indeed, since it is assumed to have happened in 1975 it never can occur in exactly those conditions. The core details of the scenario are embodied in the inputs to INFORUM shown on Table 2.

While there are numerous ways in which the economy can react, driven by either market forces or the prodding of government, INFORUM is exercised here in a manner which simulates a blend of both. It is a different approach from that used for the Vietnam War; here the hard choice is made at the onset to reduce private sector spending to free resources for

war production. Per capita disposable income is reduced to pay for increased defense goods and to induce higher employment of the labor force. This is a distinctive and key element in the approach used.

TABLE 2. INFORUM INPUT VALUES BY YEAR
(NO WAR)

VARIABLE	1974*	1975	1976
Defense Spending (Index)	(.887)	2.12(.880)	3.05(.888)
Labor Force (Millions)	(93.24)	90.46(94.79)	92.73(96.20)
Per Capita Disposable Income ($72)	(3981)	3400(4012)	3900(4175)

*Actual 1974 Values
Source: INFORUM Run 8 Jan 1977

Let us now proceed with a short description of the rationale for the input values shown on Table 2. The war postulated began on January 1, 1975.* Therefore, no change was made to any of the actual 1974 values in the INFORUM data base. And, while the reaction to stress during the first year is the focus here, further increased activity in 1976 was assumed to assure that longer lead time activities would continue throughout 1975 in anticipation of 1976.

The Defense Spending index was scaled up based on the military manpower to be supported.** Specifically, the

*The model was exercised in the same way for a war beginning on January 1, 1974 in an effort to gage the sensitivity of the results to the choice of year. Similar results were found.

**This scaling assumes no structural shift in defense spending. While there likely would be a shift, this would have to be guided by pre-war choice of vital systems and enforced with administrative vigor. Lacking either of these, given the uncertainty of the situation, the no shift assumption appears best, at least initially.

active United States military force was assumed to be augmented at the war's start by all already constituted reserves. This force was then increased linearly to ten million persons by the end of the year. Consequently, half of those indicated that had no military connection at the end of 1974 are considered in service for the year. Support for a one million man allied force (at U.S. force cost) is added to the United States force. This total is then divided by the manpower in the peacetime United States force to yield a ratio of wartime spending to no-war spending for each year considered. This ratio is then multiplied by the no-war defense spending index for that year, e.g., .880 for 1975. As indicated in the table, wartime defense spending is more than doubled for 1975 (up 139 percent from the .887 of 1974) and more than tripled for 1976. A war effort like this would be a substantial economic shock to the nation, although U.S. forces at year end would be smaller then they were in World War II (see Table 5A).*

The no-war civilian labor force was reduced by the additions to the armed forces. As Table 2 reflects, the 1975 additions to the armed forces were larger than the normal year-to-year increase in the labor force. To get maximum defense capability from the labor force a study of when (and which) workers should be inducted into the Armed Forces is needed. Optimization should be across both goods production and military actions.

*Tables that appear in an appendix have an "A" suffix.

The model was exercised iteratively to determine the per capita disposable income to be used as an input for 1975 and 1976. This exercises a feature of INFORUM which is something of a return to the practice of early input-output models which were closed systems. In this model implicit tax rates are used to achieve unemployment goals.[2] The specific unemployment rate goals used were 4.0% for 1975 and 2.4% for 1976. These rates are potentially attainable with the strong administrative support of government. The 1975 value is about 53 percent lower than the 8.5% that actually existed in 1975; the 1976 value is double the low rate achieved during World War II (Table 5A).

These unemployment rates, in conjunction with the labor force and defense spending, resulted in per capita disposable incomes of $3400 in 1975 and $3900 in 1976. This is a decrease of some 15 percent in 1975 and 7 percent in 1976 from INFORUM predicted peacetime values. It is a slightly smaller decrease from pre-war, and actual, 1974. It is unlikely that such changes would seriously impair domestic welfare. Non-defense government services were not constrained in the model and therefore are available to alleviate individual hardships. It is also important to recall that consumer durables are not fully consumed within the yearly accounting period. Especially during the first war year the large stock of these in consumer hands in the United States would be a considerable buffer. Wholesale and retail inventories of most consumer goods would further shield Americans from economic effects inherent in reduced consumer

goods production. This is a substantial wartime advantage to a rich nation like the United States. In addition, there is a high level of per capita disposable income in the modern United States. For example, a reduction of real personal disposable income to the level of early World War II would allow taxing away about half of 1975 disposable income (see Table 3A). This is an enormous aggregate potential for war production.

Realization of much of this potential would likely be politically difficult. Perhaps so much so that per capita real disposable income could not be directly trenched by tax increases without impairing work incentives. In this event, government allocations and control of strategic and critical materials, equipment, and labor could still produce the same result. They would insure appropriate real resources to vital defense pursuits while inducing added private saving of the real disposable income.

The aggregate results which flow from the model using the Table 2 inputs are displayed on Table 3. While the sectorial impacts are of prime concern, aggregates provide an indication of how the model performed in a situation significantly different from its usual peacetime forecasting use. Even with the disruptions, in 1975 the economy yielded about the same Gross National Product as in 1974, although with lower civilian employment. As expected, government purchases increased most, while exports decreased. Domestic investment also decreased, reflecting less construction and lower inventories. Declines in producers' durables appar-

ently were centered in civilian product investment--as to be expected with lower real per capita disposable income. In sum, the model appears to have performed credibly.

TABLE 3. AGGREGATE RESULTS - 1975 WAR CASE
($72B)

	1974*	1975	1976
Gross National Product	1211	1215	1289
Personal Consumption	770	774	771
Domestic Investment	169	128	180
Exports	95	88	83
Imports	-82	-73	-82
Government	259	297	338
Employment (millions)	88.2	87.0	90.6

*Actual 1974 Values
Source: INFORUM 8 Jan 1977

Now let us turn to the search for sectorial elements of the economy which might constrain a mobilization. First, the choice of how to screen INFORUM output must be made. This screening of sectors is a difficult process which nations have explored before, often in the effort to find ways to defeat an enemy quickly. Some believe that the key to victory is in finding and destroying the small, essential elements in an economy that hold the war effort together. Others believe that such elements can either not be found, or not destroyed if found. They see victory from a large, sustained pressure on the enemy. In post-World War II analysis the latter group has had the better part of the argument; Germany did not collapse because the allies found and destroyed small essential links in the economy. It has been shown that this was true because the economic principle of substitution was not properly appreciated by the first group. Alternate weapons, materials, labor, and processes

were substituted to bypass tactical shortages and to prevent strategic collapse.[3]

This same insight applies to preparedness planning. Efforts should center on finding those elements of the economy in which there is a high marginal cost in both time and resource terms in accomplishing substitution. The search for sectors which might be particularly ill suited for substitution ideally should consider all possibilities in both demand and supply. This analysis focuses upon identifying sectors which have the greatest increase in wartime demand; sectors that require much more than the average supply response. This tacitly assumes that all military goods are indeed essential. This is the basic approach historically taken by the United States.

In selecting the sectors that INFORUM calculates as experiencing the largest increase in demand, one should be clear regarding the criterion of choice. Is an absolute or percentage increase more indicative of stress? A large sector would seem more likely to experience a large absolute increase and less likely to have a large percentage increase. Those who expect the economy to fail only because of the loss of a large sector should favor an absolute change criterion. Conversely, those planners convinced that finding narrow bottlenecks are the answer might look for large percentage increases. In these sectors each experienced worker must train the largest number of additional workers or the supply of specialized materials and machines must be scaled up the most by acquiring materials, machines, and labor quickly from

other sectors. A presumption that these sectors produce larger changes in marginal cost would mean that large percentage changes are a sure indication of high stress sectors. Unfortunately, in the imperfectly competitive economy of the United States there is little warrant to presume this.

On the other hand, sectors with large absolute increases appear capable of inducing a large stress on the economy at large. Concomitantly, they may be able to shift easily within the sector, with many machines to be run a bit faster, or longer, and many workers capable of greatly increasing production with a small increase in overtime. Large sectors also are more likely to have much production for civilian uses that may be divertable to military use. At the same time, a large shortage can be a problem which may more easily expand in other directions.

Let us examine the changes in demand between pre-war 1974 and a wartime 1975 using both criteria to determine which yields the more useful insights. In the process, output will be analyzed further to assure that the model is generating plausible results. For example, small sectors with products not bought by the military and susceptible to trenching of disposable income should be large percentage decrease sectors.

Table 4 contains sectorial outputs for the fifteen sectors with the largest direct increases in demand between 1974 and 1975. Some of these increases are very large -- as high as $6.8 billion. This very rough screening does surface

some sectors with obvious defense usage. Communications Equipment, Aircraft, Complete Guided Missiles, Ships and Boat Building, Ammunition, and Other Ordnance are immediately notable.

TABLE 4. ABSOLUTE INCREASES IN FINAL DEMAND ($72M)

Sector	1974*	1975	Increases
Communications Equipment	6,739	13,552	6,813
Owner Occupied Dwellings	79,504	86,287	6,783
Aircraft	7,923	11,459	3,536
Complete Guided Missiles	4,244	6,703	2,559
Business Services	14,070	16,530	2,460
Retail Trade	124,597	127,003	2,406
Meat Products	24,355	26,233	1,878
Noncompetitive Imports	10,727	12,483	1,756
Ship & Boat Building	2,238	3,825	1,587
Airlines	7,517	8,791	1,274
Auto Repair	13,331	14,574	1,244
Trucking	3,061	4,299	1,238
Petroleum Refining	11,879	13,089	1,209
Ammunition	1,290	2,499	1,209
Other Ordnance	1,085	2,024	939

*Actual 1974 Values
Source: INFORUM 8 Jan 1977

This screening has not accounted for any of the indirect effects that input-output can be so useful in calculating. As a result, it may present a seriously distorted picture of actual wartime output shifts. Table 5 presents this more complete insight. As expected, numerous sectors shown here sell a great deal to National Defense and there is a prevalence of largersectors. Some increases, such as the $7,186 million for Communications Equipment, are startling. Note that virtually all of this increase, $6,911 million, goes directly to National Defense. In fact, this increased Defense use is more than the increase in final demand. Two sectors, Aircraft and Complete Guided Missiles, even have

increased Defense demand more than total output. Note in particular that Aircraft increased shipments to National Defense by $4,761 million while total shipments were boosted only $3,223 million.

TABLE 5. GREATEST ABSOLUTE INCREASE SECTORS

($72M)

Sectors	Yearly Output		Yearly Increase			
	1974*	1975	Total Output	Personal Cons.	Defense Demand	Final Demand
Communication Equipment	12,547	19,733	7,186	-38	6,911	6,813
Owner Occupied Dwellings	79,504	86,297	6,783	6,783	0	6,783
Business Services	67,442	71,821	4,379	173	2,013	2,460
Aircraft	9,609	12,832	3,223	42	4,761	3,536
Retail Trade	147,405	150,101	2,695	2,359	0	2,406
Aircraft Engines	3,860	6,549	2,689	-4	1,985	2,000
Complete Guided Missiles	4,388	6,999	2,611	0	2,684	2,559
Petroleum Refining	32,054	34,402	2,348	542	905	1,209
Meat Products	31,451	33,760	2,309	1,928	99	1,878
Trucking	24,371	26,382	2,011	65	1,077	1,238
Electronic Components	10,201	12,169	1,968	-8	659	42
Ship & Boat Building	3,984	5,938	1,954	88	1,770	1,587
Aircraft Equipment	4,987	6,908	1,921	-7	833	716
Airlines	14,309	16,058	1,749	161	852	1,274
Meat Animals	31,117	32,779	1,662	15	0	-606

*Actual 1974 values
Source: INFORUM 8 Jan 1977

Other sectors have significant increases in output with little direct input to National Defense. Examples are Owner Occupied Dwellings, Retail Trade, Meat Products, and Meat Animals. These are all large sectors producing personal consumption goods. In all cases their percentage increase is small, e.g., about eight and one half percent for Owner Occupied Dwellings. Their increases reflect the modest overall increase in total demand documented on Table 3.

In general, Table 5 indicates that the model has reacted realistically; it calculates large increases in the output of sectors producing for National Defense. The increases in

most of these sectors are direct and therefore relatively easy to predict without the use of a sophisticated model like INFORUM. This is seen by comparison of Tables 4 and 5. Note that eleven of the top fifteen sectors are identified using only final demand. However, four of the top fifteen sectors with large total output increases, Aircraft Engines, Aircraft Equipment, Electronic Components, and Meat Animals would not surface without the indirect demands included by input-output. This important finding may flag a grouping of sectors that are potential strategic failure points. Aircraft Engines, Aircraft Equipment, and Electronic Components all provide greatly increased input to Aircraft, a sector itself with a very large absolute increase in demand. This is probed further below.

While the primary focus here is upon the change from actual no-war 1974 to a postulated wartime 1975, a comparison of the predicted results of the model for 1975 in war and in peace documents the significant change in sectorial outputs that the scenario used in this study has made. The sectors with the largest 1975 wartime increases are seen in Table 6. Note that some of these sectors had larger no-war to war predicted increases than the absolute increases between actual 1974 and predicted wartime 1975 as shown in Table 5. This is because about half of these sectors had predicted peacetime decreases in 1975. Clearly the scenario used in this analysis substantially affected the structure of the 1975 economy, notwithstanding the modest aggregate impact indicated in GNP (Table 3). Insofar as capacity has been

based on peacetime forecasts these peacetime predictions could be important to defense preparedness.

TABLE 6. 1975 PREDICTED TOTAL OUTPUTS
($72M)

Sectors	War	No War	Increase
Communications Equipment	19,733	11,987	7,746
Owner Occupied Dwellings	86,287	82,510	3,777
Business Services	71,821	67,803	4,018
Aircraft	12,832	8,090	4,742
Retail Trade	150,101	148,029	2,072
Aircraft Engines	6,549	3,800	2,749
Complete Guided Missiles	6,999	4,234	2,765
Petroleum Refining	34,402	32,359	1,712
Meat Products	33,760	32,690	1,070
Trucking	26,382	24,476	1,906
Electronic Components	12,169	9,502	2,667
Ship & Boat Building	5,938	3,947	1,991
Aircraft Equipment n.e.c.	6,908	4,506	2,402
Airlines	16,058	14,868	1,190
Meat Animals	32,779	31,814	965

Source: INFORUM 31 Dec 1976 & Table 5

The search using the absolute increase criterion has found some sectors with large year-to-year impacts in the event of a war even if a tax increase policy is used to damp overall real GNP growth. The top fifteen sectors increased from $1.6 billion to $7.2 billion and seven of these had Defense increases of more than $1 billion. Possibly even more important is the total stress on the economy indicated by the sectorial shift to direct and indirect defense demand. The total output surge for these fifteen sectors alone is some $45.5 billion, or about four percent of GNP. In addition, there is the aggregate increase of all the other sectors with lesser increases plus about the same amount of aggregate decrease in those sectors cut. Clearly in terms of the absolute change criterion there would be a massive amount

of structural shift needed to accomodate this first year of war. Moreover, the analysis has shown which sectors would have to increase output most -- thus highlighting the areas most likely to be highly stressed.

The percentage change criterion may also yield useful insights in finding high stress sectors. Once again, we begin by identifying the sectors with the largest final demand increases. The top fifteen of these are shown on Table 7 along with five sectors which had large potential percentage gains from negative final demand totals. These latter are all sectors with large net imports. If international transportation is disrupted during a war these sectors may be particularly adversely affected. The Other Primary Non-Ferrous Metals sector includes metals which are largely imported and which are used in high technology goods, regularly as essential alloys. It is supportive of the study's hypothesis to see that this sector's final demand decrease was driven by a large decrease in imports in 1975. The decrease in civilian goods demand overbalanced the increase in defense demand. Nevertheless, the United States was still a substantial net importer in 1975.

Note on Table 7 that if direct demand alone were used that Industrial Controls is by far the most impacted, with more than twice the percentage change of the second sector, Communications Equipment. Moreover, this sector even has a percentage increase greater than the 139 percent increase in the Defense vector. However, the increase was the result of a much smaller inventory decrease in 1975 than in 1974. This

percentage increase in direct demand list is substantially different from the list of absolute direct demand increases. Only five of these twenty sectors appear on Table 4. In addition, only four of these sectors are also on the greatest absolute increase sector list (Table 5). Percentage change yields a different insight; it surfaces smaller sectors that are more defense, and possibly high technology, intensive.

TABLE 7. 1974-1975 PERCENT INCREASES IN FINAL DEMAND

($72M)

Sector	1974 Final Demand	1975 Final Demand	% Increase
Industrial Controls	48	150	214
Communications Equipment	6,739	13,552	101
Other Structural Metals	305	597	96
Ammunition	1,290	2,499	94
Nonferrous Wire Drawing	80	150	88
Other Ordnance	1,085	2,024	87
Aircraft Engines	2,423	4,423	83
Ship & Boat Building	2,238	3,825	71
Cycles, Transport Equip	505	834	65
Complete Guided Missiles	4,244	6,803	60
Miscellaneous Chemical	1,131	1,772	57
Motors and Generators	465	712	53
Materials Handling Machines	234	350	50
Pipelines	39	59	49
Engineering & Scientific Inst.	643	957	49
Saw and Planing Mills	-31	62	
Other Primary Nonfer Metals	-724	-586	
Screw Machine Products	-17	7	
Misc Fabricated Wire	-125	-63	
Ball & Roller Bearings	-48	36	

Source: INFORUM 8 Jan 1977

Once again, input-output gives a different and more complete view of the change in demand by adding indirect demands. The largest increases in total sales are shown on Table 8. Each sector has a 139 percent increase in direct National Defense sales as to be expected from the inputs (Table 2). The percentage increases in sectorial total outputs and final

demands were less than this, reflecting the fact that National Defense does not take all of the output of any sector. The increases in final demand for these sectors varies widely, from 12 percent for Electronic Components to 101 percent for Communications Equipment. Note that the increases in final demand were substantially reduced by small (or negative) increases in personal consumption. This behavior of personal consumption stems from the handling of disposable income. Note that this effect varies considerably between sectors, except for four which do not sell to individual consumption and consequently experience no change.

TABLE 8. GREATEST PERCENTAGE INCREASE SECTORS

	1974-1975 Percent Increase In		
Sector	Personal Consumption	Final Demand	Total Output
Ammunition	-20	94	66.1
Other Ordnance	5	87	61.0
Aircraft Engines	0	83	52.9
Complete Guided Missile	0	60	46.7
Communications Equipment	-22	101	45.3
Ship and Boat Building	14	71	39.9
Engr. and Scientific Instr.	0	49	33.5
Aircraft Equipment, n.e.c.	0	45	32.6
Aircraft	14	45	28.9
Water Transportation	-4	41	21.3
Electronic Components	-3	2	17.6
Machine Shop Products	11	19	15.3
Cycles, Transportation Equip.	13	65	14.2
Miscellaneous Chemicals	-8	57	13.6
Fuel Oil	2	13	13.6

Source: INFORUM 8 Jan 1977

The sectors discovered using percentage change in total output allay concern about Industrial Controls, its direct increase of 214 percent is much less formidable when we find that it has dropped out of the top ranks in total output change. Likewise, the 101 percent increase for Communica-

tions Equipment is muted by noting that there is only a 45.3 percent increase in total output. In fact, no sector has as large a percentage increase in total output as it has in final demand. For preparedness planning it is heartening that Other Structural Metals, Non-Ferrous Wire Drawing, Motors and Generators, Materials Handling Machines, and Pipelines all fall out of the top fifteen. These are all industrial infrastructure sectors historically considered major defense bottlenecks. This input-output analysis, however, shows that they are not in the ranks of the most concern; indirect usage goes up much less for these than for other sectors. As in the absolute change case, the percentage increase in direct final demand is insufficient for identifying high stress sectors. Nevertheless, direct demand is of some validity. Note that nine of the fifteen with largest total output percentage increases were identified using direct increase alone, including the top seven.

The total output percentage increase list (Table 8) identifies six other sectors, Water Transportation, Electronic Components, Machine Shop Products, Fuel Oil, Aircraft, and Aircraft Equipment, n.e.c., with large increases in total output. If all sectors are operating in linear homogeneous regions (or are all in similar non-linear homogeneous regions) then these sectors may be particularly high stress loci that are not identified without input-output.

Examination of the subsectorial impact of these six sectors reveals that in four of the six, the final demand

increase for Defense was large. This is particularly evident for Aircraft where the Defense gains in 1975 of $4762M dwarfs total intermediate and capital equipment demand of $1373M. Only Machine Shop Products and Fuel Oil were exceptions. These two sectors were characterized by relatively small amounts of final demand increased to mask indirect demand.

The Machine Shop Products sector output shows much more increase in indirect use than in Defense use. While Defense sales rose $106M, sales to Aircraft rose $111M; sales to Aircraft Engines was up $176M and to Aircraft Equipment rose another $113M. In addition, intrasectorial sales rose $52M and those to Auto Repairs were boosted $58M. Indirect increases in the sectors above were up about five times more than defense sales were. The Machine Shop Products sector is thus revealed as a possible source of indirect stress, particularly to aircraft production. This is examined further below.

As important as the large percentage increase sectors are, and notwithstanding the dramatic increase in indirect demand for Machine Shop Products, the important discovery in Table 8 is the Electronics Components sector. It is one of only two sectors with percentage increases in total output larger than the percentage increase in final demand. The other is Fuel Oil. The Fuel Oil total output increase is only .6 percent larger and predominately goes to Electric Utilities. This sector is involved in the national energy adjustments now underway, with many possible substitutions

available as the relative price of fuels shift. Electronics Components output, on the other hand, is important to defense production and not under as intense scrutiny. Moreover, the percentage change between 1974 and 1975 is much larger in this sector (see Table 8). This is an area for more detailed sectorial inquiry.

The percentage changes in total output that the high stress sectors of Table 8 were predicted to have experienced in 1975 without a war mobilization are displayed on Table 9. This documents the large change imposed on the economy and sketches the dimensions of the adjustment needed. Note that all but two of these sectors were expected to have decreased output from 1974 levels. Also note (by comparison with Table 8) that <u>none</u> of these sectors were expected to have had larger percentage increases in output without a war. Clearly we have discovered sectors in which dramatic change is likely to be necessary in a war.

In summary, the percentage change discussion has revealed a much different list of potential stress sectors than found using absolute change. It also was found, as in the absolute change examination, that different sectors are highlighted when indirect effects are added to direct effects. In a few cases, the percentage change in indirect effects is larger than that in total output. These are the cases which are particularly difficult to find and for which input-output is highly useful.

TABLE 9. PREDICTED PERCENT INCREASES IN TOTAL OUTPUT ($72M)

Sectors	1974 Output	1975 Pred. Output	Percent Increase
Ammunition	1,393	1,326	-5
Aircraft Engines	3,860	3,800	-2
Complete Guided Missile	4,388	4,234	-4
Communications Equip.	12,547	11,987	-4
Ship and Boat Building	3,984	3,947	-1
Engr. and Scientific Instr.	987	956	-3
Aircraft Equip. n.e.c.	4,987	4,506	-10
Aircraft	9,609	8,090	12
Water Transportation	3,742	3,364	-10
Electronic Components	10,201	9,502	-7
Machine Shop Products	5,210	5,083	-2
Cycles, Trans, Eqpt.	1,822	1,913	5
Miscellaneous Chemicals	4,399	4,184	-5
Fuel Oil	5,051	5,330	6

Source: INFORUM 31 Dec 1976 and 8 Jan 1977

A baseline has now been established for selection of an illustrative sector to be used for a subsectorial search for substitution opportunities. From the analysis above a number of potential candidates have surfaced by applying absolute and percentage change criteria to both direct demand and total output statistics. While no definitive reason has yet been established to prefer absolute or percentage change it is clear that the percentage change approach reveals sectors which are more explicitly defense oriented. These also tend to be sectors which present preparedness planning has considered potential problems. The choice of direct demand or total output statistics is not as difficult; the use of only direct demand can seriously mislead.

The proportion of sectorial output taken by National Defense is also a potential indicator of sectors which would be highly stressed in wartime. If Defense directly takes most output in peacetime, the 139 percent increase in defense

demand posited here could be difficult to accommodate. Table 10 displays the percentages of total output bought directly by Defense in 1974 and 1975. All sectors selling ten percent or more to Defense in pre-war 1974 are shown. Even though only ten percent is used as a definition for a defense sector it is quite startling that only twelve of the 200-odd sectors in INFORUM were directly this defense intensive. The second important finding here is that eleven of the twelve sectors were already identified on the lists of the largest absolute and percentage changes. Electrical Measuring Instruments was the sole exception, and it had only ten percent going to Defense. Third, six of the sectors, Complete Guided Missiles, Communications Equipment, Aircraft, Aircraft Engines, Aircraft Equipment, and Ship and Boat Building were on <u>both</u> the percentage and absolute change lists. Clearly those approaches make useful initial screenings for sectors greatly impacted by a large increase in defense demand.

TABLE 10. PERCENT OF SECTORIAL OUTPUTS TAKEN BY DEFENSE*

SECTOR	1974	1975
Complete Guided Missiles	44	66
Ammunition	67	83
Other Ordnance	56	73
Misc. Chemicals	11	23
Elec. Measuring Inst.	10	23
Communications Equipment	40	60
Aircraft	36	64
Aircraft Engines	37	52
Aircraft Equipment	12	21
Ship & Boat Building	32	51
Engine & Scientific Inst.	25	44
Water Transportation	17	33

*Sectors selling at least ten percent of total output to Defense in 1974.

Source: INFORUM 8 Jan 1977.

Also, as suspected, the percentage increase criterion has surfaced more direct defense production sectors.

Table 10 also reveals that, even in peacetime, a few sectors sell a large proportion of total output directly to Defense. Two, Ammunition and Other Ordnance, sold more than half to Defense in 1974. In wartime 1975, six of the twelve sectors sold more than half to Defense. Additionally, this does not include the intermediate product sales which were made to these other defense sectors. Table 11 shows the percentages of total output bought by both National Defense and by all of the defense producers shown on Table 10. In wartime, more than half of the output of ten of these twelve sectors potentially goes to these users. This table, of course, does not include those smaller percentages of these sectors' output actually used in defense production in sectors with less than ten percent of output taken by Defense (there are 124 of these sectors). On the other hand, it implicitly assumes that all output sold to sectors on this list is actually an input to defense goods. This latter fact tends to unduely increase these percentages. Nevertheless, these percentages are accurate enough to demonstrate that some sectors provide such a large proportion of output to defense pursuits that they would have relatively little civilian use that could be curtailed in wartime. Any sector with more than approximately 42 percent going to defense in 1974 could not accommodate the 139 percent increase in defense in 1975 without substituting something else. This does not mean that strategic failure will occur from these source

unless IPMs are bought and/or stockpiling is done, however. Idle peacetime capacity can be used, new capacity added in wartime, and substitution in military demand employed (if any military use is in non-vital pursuits). Nevertheless, in these sectors there should be a presumption that preparedness planning is necessary until analysis shows that timely substitutions are possible. The gravity of strategic failure dictates this. Concomitantly, the expense and opportunity cost of such measures dictate that this substitutability analysis be done forthwith.

TABLE 11. PERCENTAGE OF OUTPUT DIRECTLY TO DEFENSE AND TO OTHER MAJOR DEFENSE PRODUCERS

SECTOR	1974	1975	CHANGE
Ammunition	75	90	15
Aircraft Equipment	75	83	8
Other Ordnance	66	83	17
Aircraft Engines	67	80	13
Complete Guided Missiles	46	68	22
Communications Equipment	46	67	21
Aircraft	36	64	28
Ship & Boat Building	43	61	18
Water Transportation	44	60	16
Engineering & Scientific Instr.	35	56	21
Electrical Measuring Instr.	21	36	15
Misc. Chemicals	15	27	12

Source: 8 January 1977 INFORUM run.

The other sectors uncovered on the largest absolute and percentage change lists (Tables 5 and 8) were also checked to ascertain the proportion of their output going to Defense. Two were nine percent, and three (Meat Animals, Retail Trade, and Cycles, Transportation Equipment) had nothing going to Defense.

Any of the sectors on Table 11 that sell a large proportions of total output to defense pursuits could be a satisfactory illustrative high stress sector. Particularly eligible are those which also required large absolute and percentage changes in sectorial output in response to the Defense increase used. Three of these six produce complementary products which are inputs to a generally acknowledged potential vital defense good, aircraft. Thus, Aircraft was selected as the sector to explore further in search of timely substitution possibilities. In the process, Aircraft Engines and Aircraft Equipment are to be probed also.

Aircraft experienced the fourth largest increase in total output and the eighth largest increase in total sales. This sector also was found (Table 5) to be the sector in which the Defense demand increase between 1974 and 1975 was more than the overall final demand increase between those years. Similarly, it was the sector (Table 11) with the largest year to year change in percentage of output bought by defense producers. Aircraft also had the second largest yearly increase in Defense demand between 1974 and 1975 of all the sectors.

Let us now examine the disposition of outputs of the Aircraft sector (Table 12). This reflects the dominance of the increase in National Defense demand and that almost all non-defense final demands are reduced in 1975 from 1974. The only notable exception is the additional $42.2 million going to personal consumption. With 64 percent (8187.4 parts of

12831.7) going directly to Defense there is relatively little other end use to reduce. Airlines take a substantial part of output as capital equipment purchases but this has been cut 21 percent in 1975. This cut would be difficult in war because airlines would be required to provide aircraft for defense needs under the Civil Reserve Air Fleet program. Unless substitute transportation modes can be found or transportation uses foregone, a major bottleneck may be found here.

Table 13 is useful in determining the prospect of such substitutions in 1975. Some $4,780 million more spending on transportation use is indicated in 1975 than in 1974. This does not appear to be a substantial constraint when the percentage changes are examined. It is well known that there is substantial excess capacity in the sector. For example, the overall regulation induced overcapacity in U.S. domestic surface transportation in the early 1970s has been estimated at about 20 percent.[4] It is also well known that airlines operate with more than 12 percent excess capacity; for passenger operations, load factors of forty to sixty percent were common during the mid-1970s. However, recent deregulation and energy shortages are driving load factors up from 1974/1975 levels.

Also note on Table 13 that sectors building transportation equipment had only an aggregate two percent increase in sales in 1975. Thus, there is potential to substitute additional production of transportation vehicles. Clearly aircraft and ships are the most likely to be stressed by a war.

TABLE 12. BUYERS OF AIRCRAFT SECTOR OUTPUT

($72M)

Buyer	1974	1975	74-75% Change	74-75% Change
Agriculture	53.7	52.4	-1.3	-2
Petroleum and Gas (CE)[1]	21.5	23.7	2.2	10
Construction (CE)	19.4	18.7	-0.7	-4
Motor Vehicles (CE)	23.2	15.2	-8.0	-34
Aircraft (CE)[2]	16.1	15.9	-0.2	-1
Airlines	15.0	16.8	1.8	12
Airlines (CE)	1,276.6	1,013.9	-262.7	-21
Wholesale & Rental Trade (CE)	25.7	21.8	-3.9	-15
Communications (CE)	1.3	16.7	-4.6	-22
Finance & Services (CE)	36.1	26.3	-9.8	-27
Electric Utilities (CE)	13.4	9.2	-4.2	-31
Personal Consumption (FD)[3]	300.6	342.8	42.2	14
Defense (FD)	3425.6	8187.4	4761.8	139
Non-Defense Federal (FD)	315.0	305.4	-9.6	-3
Inventory Change (FD)	76.4	-798.8	-875.2	-1,146
Exports (FD)	3,921.8	3,582.0	-339.8	-9
Imports (FD)	120.4	163.4	43.0	36
TOTAL OUTPUT	9,609.2	12,831.7	3,222.5	29

1. CE = Capital Equipment Purchase
2. Includes capital spending of the Aircraft Engines and Aircraft Equipment n.e.c. sectors.
3. FD = Final Demand Purchase

Source: INFORUM 8 Jan 1977

TABLE 13. TRANSPORTATION SECTORS TOTAL SALES
($72M)

Sector	1974	1975	74-75$ Change	74-75% Change
BUILDING				
Motor Vehicles	58,024	54,521	-3,503	-6
Aircraft	9,609	12,832	3,223	34
Ship & Boats	3,984	5,938	1,954	49
Railroad Equipment	2,672	2,335	-337	-13
Cycles, Trans. Equip.	1,822	2,098	276	15
Trailor Coaches	3,687	3,748	61	2
TOTAL	79,798	81,472	1,674	2
USING				
Railroads	12,355	12,426	71	1
Trucking	24,371	26,382	2,011	8
Water Transport	3,742	4,629	887	24
Pipelines	1,498	1,538	40	3
Airlines	14,309	16,058	1,749	12
Buses & Local Transit	6,577	6,599	22	-
TOTAL	62,852	67,632	4,780	8

Source: INFORUM 8 Jan 1977

Exports are a major source of potential diversion of Aircraft output to defense. Some $3,582 million were exported in 1975, nearly twenty eight percent of total output. Some other sources are easily recognized sources of additional aircraft to meet defense needs. Some of these are indicated on Table 14, along with a rough estimate of the wartime military aircraft shortage which would have to be satisfied through substitution. In effect, this already presumes some direct substitutions.

The diversion of aircraft from foreign military sales (FMS) is particularly easy because FMS contracts explicitly provide for this and they regularly are perfect substitutes. In 1975, 935 military aircraft (included 478 fighters and bombers) costing $1,302M were exported. This was 17 percent of total aerospace exports and nine percent of total aerospace sales for the year.

TABLE 14. POTENTIAL WARTIME MILITARY AIRCRAFT SHORTAGE ($72M)

	Supply	Demand
Indicated U.S. Military Production[1]	3,426	8,187
Diverted from R&D, Modification, Etc.[2]		-614
Diverted from FMS[3]	896	
Diverted Personal Consumption[4]	150	
Indicated Totals	4,472	7,573
Indicated Shortage	3,101	

Notes/Sources:

1. Defense production in 1974 from INFORUM; demand from 1975 defense sales from INFORUM.
2. 1974 level maintained in 1975. 1974 effort developed from 1972 Census of manufactures levels for SICs 3721411, 3721613, & 15 and 37210.
3. 1975 FMS deflated to 1972 dollars using the industrial commodities price index from Economic Indicators, May, 1978, p.22.
4. Half of INFORUM Personal Consumption for 1974 diverted to military production.

Diversions from research and development and modification would be a substitution from activities with longer term payoffs in military and commercial aviation. The personal consumption cut allows production of military liaison-type aircraft without further burdening military producers. Even with these adjustments, the indicated shortage is still large, $3,101M. Satisfaction of this (probed in Chapter IV) is largely through diversion of commercial airline production and from increasing production.

Now let us begin the process of uncovering the potential for increasing production by examining the inter-sectorial flows that INFORUM has shown would occur in the postulated war scenario. Table 15 lists these input sectors which increased more than ten percent between 1974 and 1975 (13 sectors were less than 10%). A total of 53 sectors, more than one quarter of the total, provide inputs (sectors selling both as an intermediate good and as final demand are listed twice in Table 15 and counted once). That so many sectors provide inputs to Aircraft should be expected; aircraft are high technology goods with great division of labor and specialization of factors.

One is not surprised to find that Aircraft Equipment provides the largest input and the largest increase in inputs. Following by a considerable margin are the increases in Communications Equipment, Aircraft Engines, Machine Shop Products, and Business Services. Of these, Communications Equipment experiences the largest percentage change.

TABLE 15. INPUTS TO THE AIRCRAFT SECTOR FOR 1974 AND 1975
($72M)

Seller	1974	1975	74-75 Increase	74-75% Increase
Maint. Const.	32.7	43.6	10.9	33
Other Ordnance	11.7	15.6	3.9	33
Broad & Narrow Fabric	10.1	13.3	3.2	32
Floor Coverings	4.5	6.1	1.6	40
Floor Coverings (CE)*	6.7	7.2	0.5	36
Other Furniture	40.8	52.5	11.7	29
Paints	11.7	15.4	3.7	32
Tires & Tubes	6.3	8.3	2.0	32
Rubber Products	39.5	53.0	13.5	34
Other Stone & Clay	11.5	15.7	4.2	37
Aluminum	83.1	110.9	27.8	33
Nonferrous Rol.& Draw.	23.2	31.9	8.7	37
Nonferrous Wire Draw.	14.7	19.6	4.9	33
Nonfer. Cast. & Forg.	47.4	654.0	18.4	39
Screw Machine Products	61.9	83.2	21.3	34
Metal Stampings	105.6	141.1	35.5	34
Cutlery, Hand Tools	146.4	195.2	48.8	33
Misc Fabricated Wire	6.3	8.5	2.2	35
Pipes, Valves, Fit.	47.0	63.0	16.0	34
Other Fab. Metal	40.3	55.6	15.3	38
Mach.Tools,Met. Cut.	4.6	7.7	3.1	67
Mach.Tools,Met.Form.	4.8	6.5	1.7	35
Other Metal Working	31.7	43.3	11.6	37
Pumps, Compres., Blow.	32.4	42.0	9.6	30
Pumps, Com., Blow (CE)	6.7	8.6	1.9	28
Mach Shop Prod. (CE)	276.8	387.6	110.8	40
Elec. Meas. Inst.	17.4	22.9	5.5	32
Comm. Eqpt.	778.3	1,137.8	359.4	46
Elec. Comp.	70.5	95.0	24.5	35
Eng. Elec. Eqpt.	27.8	39.2	11.4	41
Aircraft Engines	426.2	569.1	142.9	34
Aircraft Equipment	2,244.4	2,991.2	746.8	33
Mech. Meas. Devices	18.2	23.9	5.7	31
Trucking	26.2	36.1	9.9	38
Telephone & Telegraph	100.9	133.9	33.0	33
Electric Util.	31.7	43.3	11.6	37
Water & Sewer	6.0	8.1	2.1	35
Wholesale Trade	159.4	213.9	54.5	34
Real Estate	110.2	147.2	37.0	34
Personal & Rpr. Ser.	26.4	35.2	8.8	33
Bus. Serv.	271.1	375.4	104.3	38
Post Office	9.8	13.2	3.4	35
Business Travel	117.6	161.5	43.9	37
Office Supplies	6.6	8.8	2.2	33
Unimportant Ind.	1.8	2.4	0.6	33
Computer Rental	75.4	105.7	30.3	40

* CE = Capital Equipment Purchase

Source: INFORUM 8 Jan 1977

The sector with the largest percentage increase in input to the Aircraft sector was Machine Tools, Metal Cutting. The 67 percent increase in 1975 in this sector was nearly 50 percent larger than the 46 percent of the Communications Equipment sector. This may be a classic case of a small industrial sector which is bottleneck to industrial mobilization. It was during World War II.[6] Let us examine the disposition of the output of this sector (Table 16).

Forty sectors bought metal cutting machines tools as an intermediate good but only those with an absolute increase of $5 million or more between 1974 and 1975 are listed separately. When sectors buying machine tool products as a capital equipment expense are included, the total is substantially increased; thirty-eight of the ninety capital equipment sectors buy metal cutting machine tools. In total, about one quarter of all sectors buy metal cutting equipment, an astonishing fact for a sector with only $1.2 billion in final demand (with GNP at about $1.2 trillion).

In general, these INFORUM calculations show little difficulty in satisfying metal-cutting machine tool needs, at least during the first year, if capital equipment sales react to curtailed personal disposable income as reflected here. The relatively volatile equipment investment part of GNP dropped 20 percent ($213.5M) and this essentially determined the change in final demand. While direct Defense buying rose 139 percent, it did not generate an increase in total final demand (down 8%) because Defense is not an important component of final demand for this sector. The reduction in

TABLE 16. BUYERS OF MACHINE TOOL, METAL CUTTING OUTPUT ($72M)

Buyer	1974	1975	Absolute Change	Percent Change
Machine Tools, Metal Cutting	88.3	82.9	-5.4	-6
Pipes, Valves, Fittings	19.8	25.2	5.4	27
Construction, Mine, Oilfield Mach.	31.2	36.5	5.3	17
Other Metal Working Mach.	25.7	32.4	6.7	26
Machine Shop Products	30.4	44.0	13.6	45
Communications Equipment	9.0	17.8	8.8	98
Motor Vehicles	36.8	43.3	6.5	18
Aircraft Eqpt. n.e.c.	20.2	35.1	14.9	74
Other Intermediate	208.4	263.5	55.1	26
Total Intermediate	469.8	580.7	110.9	24
Iron and Steel	43.2	53.2	10.0	23
Structural Metal Prod	23.0	16.1	-6.9	-30
Stampings	52.5	42.3	-10.2	-19
Hardware	54.0	38.9	-15.1	-28
Engine and Turbines	41.3	32.5	-8.8	-21
Farm Machinery	32.4	26.0	-6.4	-18
Metalworking Machinery	84.5	75.0	-9.5	-11
Special Metalworking	35.2	30.0	-5.2	-15
General Ind. Mach.	43.4	37.5	-5.9	-14
Electrical Appl. & Motors	12.3	7.2	-5.1	-41
Electronic Components	25.3	17.9	-7.4	-29
Motor Vehicles	249.4	163.5	-85.9	-34
Optical and Photograph	29.4	24.0	-5.4	-18
Misc. Manufacturing	20.5	15.0	-5.5	-27
Other Equipment	320.2	274.0	-46.2	-14
Total Equipment	1066.6	853.1	-213.5	-20
Personal Consumption	37.9	19.7	-18.2	-48
Defense	44.3	106.0	61.7	139
Inventory Change	17.2	-60.1	-77.3	-449
Exports	239.7	295.0	55.3	23
Imports	-264.1	-286.4	-22.3	-8
Other Final Demand	64.7	67.2	2.5	4
Total Non-Eqpt. Fin. Dem.	139.7	141.4	1.7	1
Total Final Demand	1206.3	994.5	-211.8	-18

Source: INFORUM 9 Jan 1977

inventories is large enough to have satisfied the increased direct buying by Defense.

There appears to be a major insight to the basic question of the need for IPP and stockpiling here. There is a large percentage increase needed in the input of metal cutting machine tools to an important defense sector, Aircraft. However, this input-output analysis, contrary to the experience of World War II seems to show little potential shortage of machine tool output. There are three potential reasons for this (1) this increase in demand was less than World War II; (2) the economy is larger now and more able to accommodate the change; (3) this input-output analysis is inadequate. Let us examine each of these briefly.

From Chart 3A, note that munitions production rose about 275 percent during the year after Pearl Harbor. This is more than the 139 percent increase in the defense vector used here. Thus, when we use percentage change as a criterion (1) is an answer. However, this World War II increase was only $2.75 billion (in 1945 munitions dollars); the INFORUM defense increase is much larger, more than $100 billion in 1972 dollars. Using the price index for federal purchases of of goods and services shows that the $2.75B is the equivalent of approximately $9.0B in 1972 dollars, much less absolute change than the INFORUM case.[7]

Point (2) is related because in a large economy, there are numerous opportunities to reduce temporarily sectorial demands to make goods available for a defense emergency. In this case, nearly three times as large a boost as occurred

in intermediate usage between 1974 and 1975 could have been accommodated within pre-war total final demand. Thus, (2) is valid if the absolute change viewpoint is held.

If the percentage change position is maintained however, the question of the usefulness of this input-output analysis should be addressed. Possible limitations in input-output results are addressed in Chapter V. However, the very special implicit tax policy used in this application of INFORUM has been sufficient to explain the difference from World War II. Table 3A shows that tax policies allowed real per capita disposable income to rise then and Table 2 shows that this was not the case here. The bold, and unquestionably desirable, use of tax policy here dampened overall non-defense

TABLE 17. YEARLY VALUES OF INPUTS TO MACHINE TOOLS ($72M)

Input Sector	Metal Cutting		Metal Forming	
	1974	1975	1974	1975
Rubber Products	5.9	5.6		
Steel	137.0	127.3	117.2	94.5
Copper	5.8	5.6	5.0	.2
Aluminum	6.9	6.5	7.2	5.8
Other Non-Ferrous	2.1	1.9		
Non-Ferrous Casting	1.8	1.8		
Plumbing and Heating Eq.	6.1	5.8	9.7	8.0
Screw Machines	9.9	9.4		
Misc. Fabricated Wire	3.1	2.9		
Machine Tools, Cutting	3.5	3.6		
Other Metal Working	55.9	53.9	35.4	29.6
Pumps, Compressors	20.9	19.1	9.6	7.6
Bearings	22.6	21.7	6.5	5.4
Power Transmission Eq.	20.3	18.9	24.2	19.6
Industrial Patterns	2.1	2.0		
Machine Shop Products	7.2	7.1		
Transformers & Switches	14.4	13.4		
Motors & Generators	28.9	27.2	9.9	8.1
Industrial Controls	87.0	82.1	21.2	17.4
Unimportant Industries	1.4	1.3	2.2	1.8
Computer Rental	7.3	7.3		

Source: INFORUM 9 Jan 1977

demand. In fact, as Table 17 reveals, no sector making inputs to machine tool building (Metal Forming is also shown as these machines often substitute for Metal Cutting Tools) had an increase in demand in 1975. In general, machine tool availability is not a problem, so apparently machine tool reserves maintained as an IPM are not needed. This question is probed in more detail in Chapter IV when more specialized defense production is considered.

Table 18 documents perhaps the most important fact discovered about the Aircraft sector. The sector in most cases takes less than five percent of each input sector's output in wartime. Only Aircraft Equipment appears a potential problem and that could increase output by 138 percent in 1975 if all production were divertable to Aircraft and overall production was maintained. However, recall from Table 11, much of the output of these input sectors was taken directly by Defense, particularly in 1975. Thus, if Aircraft Engines sells 52 percent to Defense there still may be a need to examine increased production possibilities for an input only constituting nine percent of output. Also, recall that

TABLE 18: PERCENTAGE OF AIRCRAFT INPUTS BOUGHT BY AIRCRAFT SECTOR[1]

INPUT SECTOR	1974	1975
Nonferrous Casting & Forging	X[2]	6
Machine Shop Products	5	6
Communications Equipment	6	6
Aircraft Engines	11	9
Aircraft Equipment, n.e.c.	45	42

NOTES: 1. Only sectors taking 5 percent or more of output shown
2. X = less than 5 percent

Source: INFORUM 8 Jan 1977

only 21 percent of Aircraft Equipment output went to Defense, so the total indicated stress of these two sectors from Defense and Aircraft are approximately the same. Inputs to these sectors are probed in more detail in Chapter IV.

The inquiry now shifts to what many consider the most technologically complex input to aircraft production, aircraft engines. While conventionally handled as a separate sector, aircraft engines are clearly complementary products with aircraft. No aircraft is useful without this major component. Moreover, the Aircraft Engine sector has already been revealed as one of possible great stress. Table 8 showed it as experiencing the third highest percentage increase and Table 5 reflected it with the sixth largest absolute increase.

Table 19 documents in more detail the disposition of Aircraft Engine output. Most engines for military aircraft are bought by the government and provided to the aircraft industry. Between 1974 and 1975 Defense experienced the largest percentage increase in purchases of aircraft engines. Note also that the second largest absolute and percentage increases appear in intrasectorial trade. As demand jumped between 1974 and 1975, there was a seventy percent increase in sales of components and subassemblies between engine manufacturers. This could indicate capacity shortages within the industry, but probably does not, because the intrasectorial disposition of engines is almost exactly the same percentage (19%) of total output in 1974 and 1975.

TABLE 19. BUYERS OF AIRCRAFT ENGINE SECTOR OUTPUT
($72M)

Buyer	1974	1975	74-75% Change	74-75% Change
Aircraft Engines	735.3	1,247.4	512.1	70
Aircraft	426.2	569.1	142.9	34
Airlines	276.0	309.8	33.8	12
Defense (FD)*	1,428.1	3,413.0	1,985.1	139
Non-Defense Federal (FD)	779.8	776.2	-3.6	0
Inventory Change (FD)	-153.8	219.5	-56.7	-37
Exports (FD)	626.1	614.0	-12.1	-2
Imports (FD)	-257.9	-170.3	87.6	34
Total Output	3,860.4	6,549.0	2,688.6	70

*FD = Final Demand Purchase

Source: INFORUM 8 Jan 1977

TABLE 20. INPUTS TO THE AIRCRAFT ENGINE SECTOR ($72M)

Seller	1974	1975	74-75% Change	74-75% Change
Maintenance Construction	18.6	31.6	13.0	70
Complete Guided Missiles	10.5	15.6	5.1	49
Wooden Containers	1.7	3.0	1.3	76
Misc Chemicals	6.2	10.4	4.2	68
Plastics & Resins	8.3	14.2	5.9	71
Petroleum Refining	43.3	73.1	29.8	69
Stone & Clay Prod.	15.1	26.2	11.1	74
Steel	156.7	262.8	106.1	68
Aluminum	36.4	61.8	25.4	70
Other Non-Ferrous	36.2	56.9	20.7	57
Other Non-Fer. Roll. & Draw.	15.4	26.8	11.4	74
Non-Ferrous Casting and Forging	70.4	124.1	53.7	76
Screw Machines	37.7	64.4	26.7	71
Metal Stampings	22.6	38.3	15.7	69
Pipe, Valves and Fittings	6.6	11.2	4.6	70
Other Fab. Metal Prod.	47.3	82.9	35.6	75
Machine Tools, Metal Form	3.6	6.1	2.5	69
Other Metal Working	139.2	241.9	102.7	74
Bearings	14.6	25.2	10.6	73
Industrial Patterns	2.7	4.5	1.8	67
Machine Shop Prod.	225.9	402.0	176.1	78
Engine Elec. Equip.	38.5	68.9	30.4	79
Aircraft Engines	735.3	1,247.4	512.1	70
Mech. Measuring Dev	3.7	6.1	2.4	65
Telephone and Telegraph	50.9	85.9	35.0	69
Business Services	155.3	273.1	117.8	76
Business Travel	84.2	147.0	62.8	75
Office Supplies	4.5	7.6	3.1	69
Unimportant Industries	1.3	2.3	1.0	77
Computer Rental	35.1	62.5	27.4	78

Source: INFORUM 8 Jan 1977

With Aircraft Engines demonstrating potential for shortages, the pattern of inputs to this sector was examined to determine which sectors would have to adjust most to keep the sector producing all that is demanded. Table 20 displays these thirty-one intermediate goods sectors. It is of particular interest that this sector, which itself provides an input to aircraft, draws inputs from ten sectors which were not included in the long list of inputs to Aircraft. This table makes it clear that Aircraft Engines requires many substantial absolute, and almost uniformly high percentage, increases in inputs. These increases, particularly in percentage terms, are larger than most of the input boosts required for Aircraft or Metal Cutting Machine Tools (see Tables 15 and 17). With many inputs increasing so substantially, one might presume that aircraft engines could not be produced fast enough to keep up with desired aircraft production unless all of these sectors have considerable excess capacity, final goods inventory, or much output quickly divertable from other users.

There is much potential to divert additional inputs to the Aircraft Engine sector. The sectorial percentages of inputs bought by Aircraft Engines are displayed on Table 21. Notice that no more than 11 percent of total sales are taken intersectorially in 1975. Unless subsectorial elements are so specialized that they can not be reoriented in production quickly enough, there should be no shortage in aircraft engine inputs. As in the case of Aircraft, some of these inputs were also sold extensively to Defense and to other

defense producers (Tables 10 and 11). The subsectorial detail of Aircraft Engines is examined further in Chapter IV.

TABLE 21. PERCENTAGE OF AIRCRAFT ENGINE INPUTS BOUGHT BY AIRCRAFT ENGINES SECTOR

Input	1974	1975
Wooden Containers	1	1
Stone and Clay Products	X	1
Steel	X	1
Aluminum	2	3
Other Nonferrous	4	6
Other Nonferrous Roll. & Draw	1	2
Nonferrous Castings & Forgings	7	11
Screw Machines	1	2
Other Fabricated Metal Products	1	2
Machine Tools, Metal Forming	X	1
Other Metal Working	2	3
Bearings	1	2
Machine Shop Products	4	7
Engine Electrical Equipment	4	8
Aircraft Engines	19	19
Business Travel	X	1
Computer Rental	1	1

NOTES: 1. Only sectors providing more than .5 percent of output shown
2. X = Less than .5 percent

Source: INFORUM Jan 1977

Through the use of INFORUM there have been a number of significant findings made in this chapter. Sectors which have large increases in direct demand and thus might be presumed to be the most stressed in a war are revealed as not being the most potentially stressed when indirect usage is added. This result obtains whether an absolute or a percentage yearly change is used. The Aircraft Engines, Aircraft Equipment, Meat Animals, and Electronic Components were the sectors thus revealed as possible problems. At the same time, Industrial Controls was found as not the apparent problem the more naive approach indicated. It was also found that a percentage change criterion tended to identify sectors that need to adjust substantially to provide defense goods

somewhat better than the absolute change criterion. This was particularly evident when the proposition of output being taken by Defense and other major defense producers was examined.

The prevalence of competition for resources between sectors all of which are producing defense goods was examined. Eight sectors, Ammunition, Aircraft Equipment, Other Ordnance, Aircraft Engines, Complete Guided Missiles, Communications Equipment, Ship and Boat Building, and Water Transportation were found as providing such a large proportion of output directly to Defense, or to other defense producers, that capacity increases, substitution in defense demand, and/or existing excess capacity would be necessary in wartime. In addition, an exceptionally large 1974 to 1975 percentage increase in outputs going to defense was uncovered for Aircraft (caused by a decrease in the large volume of sectorial exports). This placed Aircraft in the ranks of those which sent more than 60 percent of wartime output to defense.

The aircraft industry, comprised of the Aircraft sector and its closely related input sector, Aircraft Engines, was selected for more detailed analysis. This industry produces a clearly important, perhaps vital, military good, for which demand increases greatly in wartime and is technologically advanced, thus leading to fears that substitution may be difficult and time-consuming. These fears are strengthened by the finding that particularly in wartime a large percentage of sectorial output goes to defense use. The

general pattern of inputs and outputs of this illustrative industry have been established in preparation for the more detailed work in Chapter IV.

The next important finding was that sectorial outputs are regularly distributed to a wide range of sectors, indicating many potential avenues for substitution in product demand. Likewise, it was found for an illustrative high stress sector that there is an very broad range of inputs; this provides potential for bottlenecks and substitution. The INFORUM results showed that it is likely that the machine tool industry may not be a bottleneck today, although it was during World War II, because output is widely distributed and because tax policy can help substantially in dampening industry demand. A further finding is that the aircraft engine industry may have a problem in supporting timely aircraft production. The fact that both Aircraft and Aircraft Engines use only a small fraction of the total output of their input sectors has far-ranging implications for the further search for substitution possibilities in later chapters. Only a relatively small number of defense goods producing sectors appear as possibly constraining this finding.

IV. AIRCRAFT PRODUCTION

INFORUM has been used to identify an industry, aircraft, that can be expected to experience much greater than average wartime stress. This chapter builds upon the INFORUM baseline to determine if a more detailed examination of the inputs to aircraft production reveals substitution opportunities which could make present IPP and stockpiling programs unnecessary. Some of the attention is far removed from the direct fabrication and assembly of the final product, military aircraft, because of the substantial division of labor and production specialization in this industry. The chapter introduces more INFORUM insights and draws in much more information on potential supply constraints from other sources.

The closer an input is to the final product in the production process the narrower the range of possible substitutes and the more substitution time likely is needed. Consequently, more flexibility inheres in the manufacture of minor components, in materials' use, and in producing the machinery used to manufacture defense goods, than in defense goods themselves. The components in the final product may be rigid in specification, but the factors employed indirectly need only perform the requisite function. For example, a particular type or model of machine tool often is not necessary. The need is only that the component can be formed within the allowed tolerances of shape, internal stress, etc. The size and diversity of the United States economy provide many alternatives for doing this.

Broad economic aggregates such as used in INFORUM tend not to reflect the time consuming problems that might occur in making alternative choices of inputs far up the production sequence. However, if the aggregates do not indicate sufficient overall capacity, possibilities of detailed capacity being available without IPP and or stockpiling are greatly reduced. Some aggregates that are particularly important for the first year of a mobilization are inventories of final products, intermediate goods and raw materials. These are the buffer stocks that allow the economy to function as the necessary restructuring of production occurs. Inventories are the most rapid and perfect substitutes, but tend to cost the most. In assessing the potential for greatly increased aircraft production let us first examine some inventory aggregates, particularly those for durables in the machinery and transportation sector. After this, subaggregates of machinery and transportation used in aircraft are addressed.

Because of the high carrying cost of inventory and the improved forecasting of demand, there reportably has been a downward trend of inventories in proportion to sales in United States manufacturing.[1] However, the data on Table 22 show that this trend was not strong for broad production aggregates through 1974, the base year for this study. It is somewhat evident for nondurables, but this study is generally interested in durables. Table 23 further reflects that for the machinery and transportation portions of durables that there has been a strong uptrend in inventories with the trend being somewhat stronger for materials and goods-in-process

than for finished goods. At least through 1974 there was not a downtrend in inventories for this part of the economy. This is supportive of this study's hypothesis.

TABLE 22. INVENTORY TO SALES RATIOS

YEAR	TOTAL BUSINESS	DURABLES	NONDURABLES
1958	1.60	2.23	1.45
1959	1.50	2.00	1.39
1960	1.56	2.07	1.42
1961	1.54	2.05	1.43
1962	1.51	1.98	1.44
1963	1.49	1.94	1.42
1964	1.47	1.87	1.38
1965	1.45	1.81	1.34
1966	1.47	1.85	1.34
1967	1.57	2.09	1.37
1968	1.55	2.05	1.36
1969	1.57	2.08	1.36
1970	1.64	2.31	1.39
1971	1.61	2.22	1.37
1972	1.53	2.03	1.29
1973	1.46	1.91	1.20
1974	1.50	2.06	1.19

Source: U.S. Department of Commerce, Business Statistics, May, 1976, p.26

This insight is reinforced when these sectors are further disaggregated and adjusted for price and population changes. Table 25 displays these data for a number of sectors which were revealed in Chapter III as potential high stress sectors (trucks and truck trailers are shown for comparison only). In real per capita terms there is no general pattern of downtrend evident. Table 24 further reveals that industries have run strongly toward a higher ratio of inventories to sales. The real trend is not just reflective of a larger economy. Note that Aircraft almost doubled during this period. In addition to this trend in the inventory/sales ratios in aircraft production, the ratio is much larger in this industry than in

the others. This may reflect government progress payments as well as the ever longer production process. There also is a pronounced capital deepening in the Aircraft Engine sector. Apparently these sectors are significantly different from most industries. It is likely that this reflects the fact that these industries produce relatively small numbers of each individual output. For such industries, this results in disproportionately large inventories per unit of output to insure smooth production flow. In fact, for aircraft and aircraft engines it is likely that production is in a range of increasing returns. This is implicit in the slope of the learning curves for production aircraft. This would be the underlying reason for industrial fact in recent years that it is easier to produce incremental aircraft from a higher baseline production rate than from a lower one. The implication of this is very supportive of the study's hypothesis, up to the production rate where diminishing returns sets in.

It is possible that these inventory data and their trend give false comfort because the data are incorrect. Indeed, there are significant limitations (see Chapter V) to a wide range of economic data, and inventories are known as particularly suspect.[2] There is proprietary interest in concealment for tax and/or competitive reasons. Additionally, concealment has been aided by recent widespread shifting from FIFO to LIFO accounting. It also is increasingly realized that economic aggregates, and particularly inventories, are importantly affected by expectations.[3] Expectional effects should be important in preparedness planning, but there is generally

TABLE 23. MACHINERY AND TRANSPORTATION EQUIPMENT INVENTORIES ($B)

YEAR	MACHINERY MATERIALS	MACHINERY IN-PROCESS	MACHINERY FINISHED	TRANSPORTATION EQUIPMENT MATERIALS	TRANSPORTATION EQUIPMENT IN-PROCESS	TRANSPORTATION EQUIPMENT FINISHED
1958	2.4	3.7	2.7	1.6	4.3	.7
1959	2.8	4.2	3.0	1.8	4.3	.7
1960	2.7	4.3	3.2	1.7	3.9	.8
1961	2.7	4.7	3.1	1.7	3.8	.7
1962	3.0	5.4	3.4	1.8	4.1	.8
1963	3.0	5.6	3.6	2.0	4.4	.8
1964	3.3	6.2	3.7	2.3	4.8	.8
1965	3.9	7.1	4.0	2.5	5.3	.9
1966	4.9	8.6	4.7	2.8	6.7	1.1
1967	5.2	9.3	5.2	3.2	8.5	1.2
1968	5.4	9.8	5.3	3.2	10.2	1.4
1969	6.2	11.0	5.9	3.3	10.0	1.5
1970	6.2	11.0	7.0	3.3	10.8	1.5
1971	6.1	10.5	6.9	3.3	10.0	1.5
1972	6.5	11.3	7.0	3.0	11.8	1.6
1973	8.4	13.4	7.5	3.9	12.8	1.6
1974	11.3	15.9	9.1	4.9	14.2	1.9

Source: U.S. Department of Commerce, Business Statistics, 1975, p.32.

TABLE 24. PER CAPITA REAL INVENTORIES FOR SELECTED INDUSTRIES
($72)

YEAR	TRUCKS	TRUCK TRAILERS	METAL CUTTING	METAL FORMING	AIRCRAFT	AIRCRAFT ENGINES	ENGINE ELEC. EQUPT.	INDUSTRIAL CONTROLS
1958	.44	.58	1.87	.84	20.0	4.6	.67	.57
1959	.46	.66	1.96	.95	19.0	4.1	.87	.63
1960	.46	.52	2.03	.94	15.3	4.3	.79	.69
1961	.45	.58	2.00	.98	14.8	4.4	.75	.71
1962	.59	.57	2.07	1.00	15.9	4.4	.87	.78
1963	.46	.51	2.29	.90	17.7	4.3	.72	.86
1964	.55	.60	2.44	.98	16.5	4.5	.77	1.01
1965	.59	.75	2.72	1.14	15.9	5.0	.90	1.14
1966	.76	.83	3.24	1.25	21.6	6.9	1.11	1.47
1967	.73	.75	3.39	1.32	33.2	6.7	1.12	1.42
1968	.82	.85	3.26	1.29	37.7	6.8	1.02	1.44
1969	.91	.86	3.52	1.33	42.2	7.1	1.15	1.55
970	.93	.68	3.01	1.38	37.2	5.7	1.44	1.42
1971	1.00	.70	2.46	1.17	30.0	5.2	1.26	1.23

Note: Personal consumption durable goods price deflator used for truck and truck trailers. Non-residential private investment deflator used for others.

Sources: U.S. Department of Commerce, 1972 Census of Manufactures, appropriate industry series, Table 1A.—inventories.
U.S. Department of Commerce, Business Statistics, 1975 edition, p. 5.--price deflators.
U.S. Department of Commerce, Statistical Abstract of the United States, 1975, p. 5.--population.

TABLE 25. INVENTORY/SALES RATIOS OF SELECTED INDUSTRIES

YEAR	TRUCKS	TRAILERS	TRUCK TRAILERS	METAL CUTTING	METAL FORMING	AIRCRAFT ENGINES	ENGINE ELEC. EQPT.	INDUSTRIAL CONTROLS
1958	.20	.24	.34	.33	.38	.16	.14	.17
1959	.18	.19	.33	.34	.36	.15	.14	.16
1960	.17	.18	.30	.32	.34	.18	.13	.17
1961	.18	.21	.32	.31	.33	.18	.13	.17
1962	.18	.14	.29	.30	.35	.16	.13	.18
1963	.15	.16	.30	.28	.39	.15	.11	.18
1964	.18	.17	.27	.28	.35	.17	.12	.20
1965	.17	.18	.26	.28	.32	.18	.12	.20
1966	.17	.18	.27	.26	.36	.24	.13	.21
1967	.18	.18	.25	.29	.47	.20	.13	.20
1968	.19	.19	.26	.30	.48	.21	.11	.21
1969	.21	.17	.29	.32	.60	.24	.13	.22
1970	.19	.17	.31	.33	.61	.21	.15	.23
1971	.20	.18	.36	.35	.60	.23	.13	.21
1972	.19	.17	.34	.35	.73	.24	.12	.23

NOTE: All ratios calculated by dividing end year inventories of final goods by that year's shipments.

Sources: U.S. Department of Commerce, 1972 Census of Manufactures, appropriate industry series, Table 1A.

AD-A116 776 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH F/G 15/5
THE ECONOMICS OF INDUSTRIAL PREPAREDNESS PLANNING AND RAW MATER--ETC(U)
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UNCLASSIFIED AFIT/NR/82-15D NL

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poor linkage between economic statistics and economic agents' behavior. The probable bias caused by this is examined in Chapter V. It is likely that economic data tend to understate economic potential in a crisis.

It has been established that there are substantial inventory levels in the aircraft industry and supporting industries to help create the large production surge postulated during the first war year. Let us examine the other inputs that are needed for production. Facilities, labor, aircraft engines, materials, stock items, machine tools, engineering and scientific test instruments, and other metal working equipment and related tools and dies are covered in this order.

Aircraft production facilities need little attention because the industry is not a mass production one. Therefore, there is less specialization of structures and built-in equipment than in many others. As a result, much production could easily be transferred to other facilities if necessary in an emergency. Additionally, a study of facilities concluded that in 1975 there was about 45 percent overcapacity in the industry when using a nominal one shift capacity measure and about 80 percent overcapacity when using a mobilization measure.[4] The nation now has much more aircraft plant capacity than it had during World War II and that experience showed that factories built for other purposes can be transformed quickly to aircraft assembly and fabrication.[5]

A more difficult input to assess is labor. The INFORUM analysis generated an increase in personpower demand between

1974 and 1975 of 159,000 (31.7 percent) for an aggregate Aircraft, Aircraft Engine, and Aircraft Equipment sector. There are limitations to this INFORUM indicator because it assumes that the relationship between output and labor at past high levels of production can be extrapolated. While this incorporates implicit adjustment for changes in labor productivity it does not consider the effects of changes in worker motivation as demonstrated in past wars. With conventional peacetime microeconomic insights one expects a decrease in labor productivity because of diminishing returns.

If peacetime increasing returns in aircraft production applies to labor or if it is correct that labor, particularly skilled labor, is hoarded in this industry, then these projections understate possible wartime production. In addition, the World War II experience showed that the effect of diminishing returns was low in wartime. Manufacturing manhour productivity fell only 5.5 percent between 1940 and 1944 (Table 8A) and productivity per worker rose 12.1 percent. Moreover, the increase in defense was larger than postulated here. From Chart 3A note that the first war year (December 1941 to December 1942) increase in defense production was approximately 270 percent. Because Chart 3A presents overall munitions production, not just technologically sophisticated items such as aircraft, aircraft production statistics for this period were also examined. They indicate a 224 percent increase in aircraft production, and from a base of significant size (454 aircraft) although

smaller than the 1974 base of 1110 (Table 1).[6] Thus, even with a large jump in output, labor productivity did not drop. A more extensive discussion of the World War II circumstance is found in the appendix. It concludes that labor hoarding was not prevalent throughout the prewar period. However, possibly some workers developed exceptional substitutability that served the nation well during the war. Today, labor force participation rates are higher than at the beginning of World War II, leaving a smaller proportion of potential labor force entrants in the population. In addition, the average manufacturing workweek was longer in 1974-75 than in 1939-40. Another indication of tight labor markets now is that the percentage of multiple job holders was 5.8 percent for men and 2.6 percent for women in 1974. While such data are not available, these levels probably were lower in 1940.[7]

Particularly important to the labor question is the availability of skilled craftsmen. Defense production in general requires 20 percent of the workforce as craftsmen (about 50% higher than the general economy) and 15 to 22 percent of patternmakers, sheetmetal workers, machinists, and tool and die makers produce defense goods during peacetime.[8] Without a wartime productivity increase, a 139 percent increase in military spending might require between 36 and 53 percent of these specialties in defense industry. However, with a choice to use only existing weapons models, new patterns are unnecessary and new tools and dies can be copies of existing ones, so not all skills would need an upward shift

of this size. Nevertheless, defense demand for machinists and sheetmetal workers could expand to about 48 percent of those available. In particular areas, defense demand might increase more.

The extent of the possible labor problem is now probed using a large military goods producer in the Aircraft Engine sector, Pratt and Whitney. This sector was found likely to be under great stress in Chapter III.

During 1975, total manufacturing employment in Connecticut was approximately 400,000 with about 150,000 in the Hartford-Bridgeport area near the major Pratt and Whitney plants.[9] With 20,000 people working directly for this one firm, it is a major factor in the local labor market. It would seem difficult to hire 22,000 additional hourly production workers plus overhead personnel in time to produce aircraft engines to install in aircraft by the end of the first war year. The supply elasticity for workers over several months may be low. However, the hiring experience at aircraft engine plants at the beginning of World War II is optimistic. As now, there were only two premier aircraft engine producers (Pratt and Whitney was one). The industry had approximately 16,000 workers at the end of 1940 and almost 39,000 by the end of 1941, a percentage boost of about that envisioned here.[10]

The solution to achieving such an increase lies in subcontracting to firms not now in the defense business. This leaves workers in place working on already positioned, familiar machines. Such dispersal of activities would be an added administrative, and perhaps transportation, burden but could

be manageable quickly if plans to do so were readily available. If the World War II experience is repeated, problems in local labor markets from such a shift could be a significant part of the administrative burden.[11]

Even with task dispersal, there is a need for more workers at the main fabrication and assembly centers and some may need to be trained quickly. This is clearly impossible if traditional apprentice training is used.[12] Fortunately, there is a faster way. Employment and Training Administration (ETA) programs provide training of widely varying duration. With ETA it takes about 4000 hours for on-the-job training (OJT) and about 120 hours for off-site qualification in fabricated metal products, electrical and non-electrical machinery, and transportation equipment skills. Skill improvement programs take about 500 and 80 hours respectively.[13] These programs offer hope for rapidly qualifying defense workers, and they could be a significant factor in skill improvement.

These times also are likely to understate capability. Other ETA programs have produced workers able to operate machines and perform a variety of high skill manufacturing functions in from eight to sixteen weeks of classes and twelve to forty weeks of OJT. This effort, begun in 1964, has now matured and is using a twelve week class plus twelve week OJT approach. In 1967-1977 the overall completion rate of 67 percent (692 of 1032 enrollees) was higher than the 58 percent average over the years.[14] This program is a significant potential for worker training in and near defense plants

for first year war production. The best of the trainees from this program produce about as well as the average four year apprentice program graduate.[15] Inducements to high quality individuals to enter such a program in wartime could quickly increase the number of graduates. Furthermore, if the program were made more intense (consistent with longer workdays and weeks) there would be less than a six month lag in labor supply from this source. With a six day, forty eight hour work week, as during World War II, there would be an indicated 2.4 week gain. Similar telescoping of the off-site part of the course might result in a month being cut from the peacetime 24 week program. Additional gains could result from narrowing the range of skills taught to each.

The major underlying economic insight is that increasing the division of labor reduces the training time for each task. On balance, labor is not an insurmountable problem. However, it is clear that the administrative capacity to hire, train and move workers quickly is needed. Many opportunities for substitution exist, but some labor IPP is likely to be needed to guarantee that results are timely. Present preparedness planning is not sensitive to the labor dimension, however.

The third input to be analyzed further is aircraft engines, a product highlighted in Chapter III as particularly difficult. On Table 21 it was shown that sectorial input increases ranged from 49 to 78 percent. If subsectors were completely disaggregated to specialized military components, all would rise 139 percent, the Defense increase. In any

event, all components of military engines are needed well within the one year planning horizon so that assembly can be completed in time. Let us use the case of Pratt and Whitney to examine this. The firm builds at least twelve major engines, and nine have military applications.[16] A wide range of parts must be bought by, or produced in, the company for each of these engines. In wartime, a substantial potential problem for parts production is created if the engines compete for company subcontractor capacity. The problem would be eased if some defense programs were cut back, but that is not envisioned in this study.

Several of the military engines share commercial applications, but three key ones do not. These are the F100 which powers the F-15 and F-16; the F401 used in the F-14B; and the TF30 used in the F-111, A-7, and F-14A. For Navy use some substitution of F-14A and F-14B parts is feasible, but no quick substitute is possible for the F100. Both aircraft it powers are high priority, potentially vital systems.

Pratt and Whitney studied the ability to produce F100 and TF30 engines and spare parts used in operational military engines in 1975. The approximately 39,000 parts contained in these engines were screened in essentially a peacetime scenario to see if they were likely to need capacity analysis. Some 3,000 parts were analyzed with detailed data and possible IPMs were developed for 300. Similar effort was expended at the part type level for the other 2700. The study then examined the firm's subcontractors' capability to produce components. Of the approximately 31,000 parts pro-

duced by subcontractors, 22,000 had sufficient capacity, and only a few had a shortage for which the firm did not know of open capacity elsewhere. However, the overall conclusion was that requirements smaller than used here in INFORUM could not be met within two years. The reasons were median component lead times of 14 months for the 300 studied at the part level and of 8 months for the 2700 parts groups.[17]

One could judge from this that IPP is essential for timely production of military engines, and therefore for complete aircraft. This ignores the facts that have been uncovered in this study, that there is much non-defense industrial potential in the nation. Many additional component suppliers exist beyond in-house capacity and customary subcontractors and suppliers. Moreover, in wartime government can direct this capacity as well as present subcontractor capacity away from commercial commitments. For example, in wartime the nation would not wait 18 months to receive a compressor (P&W stock number 677785) as this study assumed.[18]

Additionally to save time in a mobilization the firm could contract out all parts which can be produced on the designated schedule by suppliers and retain all others for production at the prime contractor. Thus, technologically difficult parts would be produced by the most capable producer and transportation time would be minimized for these cases. With substitution, considerable time can be saved.

Now let us assess further the engine production potential to satisfy the INFORUM scenario. To get F-14s, F-15s, F-16s, F-111s, and A-7s in time, Pratt and Whitney engine designs

must be used. First, let us gage the firm's machining potential rather closely. It possesses approximately 6500 machine tools at various plants, and subcontractors employ many more, perhaps thousands.[19] Most of these are located in the Bridgeport-Hartford area where there were 142,000 machine tools in 1973. Moreover, there were an additional 193,000 in the greater Boston area (and 3,065,500 nationally).[20] Clearly there is considerable metal working capacity which might be diverted to produce the Pratt and Whitney parts needed for a 139 percent increase in production.*

The same sort of diversion of existing capacity that can be done under provision of the Defense Production Act can be used to provide more raw materials and mill shapes. The real problem is to change existing contractual and customary supply arrangements. Commercial stocks typically are sufficient for several months production, even at wartime levels. The general availability of materials, stock items, and machine tools is analyzed farther below in a context of overall aircraft production.

Let us now summarize how the indicated first year engine shortage could be filled. First, as seen on Table 13, significant output can be gained from diverting military exports, personal consumption, research and development, and modifica-

*Machine quality is a likely constraint with specialized machines. Five axis milling machines are a notable example. Because of high unit cost, such machines have high peacetime utilization rates. However, even these machines are used regularly on jobs which do not require their unique features, so considerable substitution is possible.

tions. This leaves about a 90 percent yearly increase in military aircraft and engines to be attained from diversion from commercial aircraft capacity, from increases in inputs from other sectors, and from production boosts within this sector.

Approximately 48 percent of peacetime aircraft engine production is for nonmilitary customers.[21] Not all of this could be transferred rapidly to military production because at least some of the goods-in-process for large civilian aircraft jet engines would be too specialized. If only two-thirds of civilian capacity is diverted to military production during the year, and it is done in a linear fashion, then about 16 percent of the 90 percent gap can be closed.

The immediate pacing item is components. As shown on Table 18, at the end of 1974 durable goods manufacturers had 2.06 years of sales in inventories. In that same year work-in-process inventories in machinery production were 48 percent of total inventories.[22] If aircraft engines were typical durables, about one peacetime year's sales existed as goods-in-process. At the wartime activity levels postulated this yields about five months of goods-in-process, assuming the mix is balanced. However, only military engine goods-in-process is assured of being timely, and many parts are not standardized between engines of these advanced types. Consequently, inventory would get used up in less than five months.

This is where the pronounced specialization of materials, production standards, and intermediate product definition has

most changed the producibility of defense goods since World War II and possibly created a technological Maginot Line. In addition, administrative requirements, codified in the Armed Services Procurement Regulations, and the relatively slow process of certification of new producers have further inhibited rapid production. Such factors make it difficult to sustain production at primary plants by involving new producers, subcontractors and suppliers. Many suppliers now are involved as indicated by the 31,000 of 39,000 Pratt and Whitney parts not produced by the primary contractor. In addition, subcontractor and supplier ability to keep pace with the prime contractor is quite uncertain. Most are small firms with different problems in changing production mix and less financial capability. In fact, these stringent production and administrative requirements and relatively small financial capability were generating a rapid contraction in numbers in the 1970s.[23]

Those subcontractors and suppliers that remain are less willing to purchase increasingly specialized equipment to make defense components. In addition, those small firms that remain rarely use such machines intensively because they usually cannot support multiple shifts. Consequently, they tend to have more multiple shift surge capacity than prime contractors. Furthermore, because they usually are job shops they have above average ability to switch production mixes quickly. This capacity, along with that diverted from present non-defense suppliers, is the key in overcoming the remaining indicated shortage.

If present defense firms divert labor, materials, and other input from non-defense firms so as to open a second forty hour shift by the end of the year, this would greatly boost production. If the buildup were linear, this would yield another 42 percent (.52 x .5 x 100 + .48 x .33 x 100) boost in military engine production, assuming no returns to scale or diminishing returns. This leaves about 32 percent in shortage. In an emergency a longer workweek would be made standard in a vital industry such as this. A six and one-half day week is probably feasible as far as equipment and facilities maintenance is concerned. Going to only a six day (forty-eight hour) week for both shifts of present defense workers, the average of one-third of present civilian aircraft engine production and for a half-year of the new second shift would yield an additional 22 percent boost in production. Only a 10 percent increase would not be in sight, and such an increase should be possible from wartime increased motivation that yields a per unit productivity change. This subject is examined in Chapter V.

Some of the implicit assumptions in the foregoing rough estimate may be difficult to achieve. For example, hiring and materials availability may make a linear buildup difficult throughout the year. However, there is much potential not included here still available: a third shift could be added along with work on the seventh day of the week. More importantly, completely non-defense facilities and equipment could be brought into defense production. In addition, the hard choice could be made to shut down all civilian engine

production. There is considerable safety margin when an aggressive substitution program is used that is sensitive to the need to conserve time for vital production during a war.

Next, the availability of materials for aircraft and aircraft engines production will be examined. The INFORUM results in Chapter III have found no metals sectors among the greatest absolute or percentage increases. This seems surprising because metals are highly volitile in business cycles and because each element in the defense vector increased by 139 percent and military goods are about twice as metals intensive as industrial products in general.* The INFORUM performance of the metals sectors is summarized on Table 26. The increases are modest. Indeed, the decreases in steel and lead do not make this appear a traditional mobilization. It is not, because of the way that per capita disposable income was controlled. With such an approach, and the successful control of expectations, there is no apparent raw materials problem unless for minor nonferrous metals which might have imports interrupted.

Aircraft and aircraft engine production use the materials shown on Table 27. This list includes most of the materials

*It is possible that wartime production would need to be much more goods (and therefore metals) intensive than defense expenditures in peacetime. If so, this would drive up the percentage increase in metals usage. _A priori_ it is not clear that the defense vector would become much more goods intensive, at least during the first war year, because military manpower levels would be dramatically increased, thus increasing personnel payments. In so far as prewar materiel reserves are inadequate, or that materiel attrition is higher than personnel attrition the metals ratio would be driven up.

on Table 26, although in strikingly different porportions. To produce aircraft in a timely way these materials are essential with little opportunity for substitution within aircraft production.

TABLE 26. TOTAL SALES OF SELECTED METAL AND METAL ORE SECTORS ($72M)

Sector	1974	1975	% Change
Iron ore	1,199	1,282	7
Copper ore	1,641	1,727	5
Other nonferrous ore	697	714	2
Steel	39,940	39,602	-1
Copper	6,432	6,694	4
Lead	567	485	-14
Zinc	501	461	-8
Aluminum	7,663	7,772	1
Other nonferrous metals	869	935	8

Source: INFORUM 8 January 1977.

TABLE 27. PROPORTIONS OF MATERIALS IN USE IN AIRCRAFT AND AIRCRAFT ENGINE SECTORS* (Percent)

Materials	Aircraft	Aircraft Engines
Steel	13	67
Copper	8	2
Aluminum	58	13
Titanium	16	18
Woven fabrics	5	--
Total	100	100

*Direct use, percent of value, totaled by sector.
Source: U.S. Bureau of the Census, 1972 Census of Aerospace Equipment, Including Parts, pp. 37B-29-30.

Fortunately materials restriction is not serious because most have many alternative uses. For example, the 1975 INFORUM consumption of aluminum in the Aircraft and Aircraft Engine sectors was 1.4 and 0.8 percent respectively of peacetime 1974 total sales.[24] Copper is affected even less, with only 0.1 percent of total sales going to each of these sectors. This much could be provided from existing commercial

inventories, the quickest and cheapest substitute source. This partial equilibrium approach could be risky if many defense and civilian goods producers want more simultaneously and if defense were a high proportion of total use. As we see the defense portion is not large and the demand reduction forced on civilian use has helped.

The root of the concern in raw material availability is the potential for supply interruption from imports and the exhaustion of commercial inventories. Net aluminum imports were \$73.8M in 1974 and an indicated \$86.0M in wartime 1975. Simultaneously inventories were reduced \$54.5M in 1975. This wartime import deficit plus inventory drawdown was less than two percent of 1974 sales and less than annual peacetime sales fluxuations. (In 1973, aluminum total sales were almost 8 percent larger than in 1974.) Furthermore, in 1975 net imports are still at about the 1973 level. The situation is somewhat worse for copper in that net imports were about 8.4 percent of total sales in 1974 and about 4 percent in 1975. However, the inventory drawdown in 1975 was only about 1.5 percent. Once again, import losses leave the nation at approximately peacetime 1973 levels of consumption. Similar results obtain for the copper ores sector.

While there is no indicated need to substitute materials for aluminum and copper or to hold a national defense stockpile, it is possible that other nonferrous metals with a larger proportion of output taken by defense may be a concern. INFORUM output is of little help in evaluating this because these metals are aggregated in the Other Nonferrous

Ores and the Other Primary Nonferrous Metals sectors. Some observations that can be made are that net imports were a larger proportion of total sales (45 percent for Primary Non-Ferrous Metals and 11 percent for Nonferrous Ores) in 1974 and that even though aggregated, these sectors are small (see Table 26).

With modest sectorial percentage gains in 1975 there would appear to be no reason for concern unless, subsectorial percentage gains are large. Table 27 indicates that titanium, which is used extensively in aircraft and aircraft engine production and not very extensively in other uses, may be a problem nonferrous metal, particularly because there may be insufficient inventories of raw material and goods-in-process, especially forged forms, available. Titanium aircraft parts bear very high stresses and specialized management of them is customary so that final parts can be traced to the original billet. Because of the potential shortage of titanium, let us examine its use and availability in more detail.

At the end of 1974 about 2.2 months worth of primary sponge was in private hands, using peacetime consumption rates. Net imports were about 14 percent of consumption with about one-fourth coming from the Soviet Union and much of the remainder from Japan. Another 12 percent came from the government stockpile. These factors indicate that more titanium must be produced or the metal stockpiled for war. This is reinforced by the fact that, unlike copper and aluminum, about 87 percent of titanium metal produced in 1974 went into

jet engines airframes, and space and missile applications and some of the remainder went to Ordnance. This left little to divert to aerospace in wartime.[25] While published Commerce Department data do not portray production figures because of company confidentiality, one calculates that at least 12,375 short tons were produced in 1974 (see Table 28). When this is compared with the estimated capacity of 18,000 short tons, it appears that peacetime production levels could be attained within the United States. However, unless imports from Japan can be increased and assured, a stockpile appears necessary to accelerate aircraft production in time. The 4,600 tons of export scrap could be processed by United States firms and the system purged of scrap, but this would not last long. Titanium scrap is of high value and is normally carefully collected, leaving little slack. Therefore, it is necessary to explore the possibility of quickly expanding domestic titanium metal production. To do so first requires the availability of ore and then the sponge production capacity.

TABLE 28. TITANIUM STATISTICS FOR 1974

Category	Short Tons
Consumption	20,500
Imports	7,500
Exports (mainly scrap)	4,600
Net from government stockpile	2,485
Year end inventory	3,800
Inventory change, 1974	1,860
U.S. capacity (est.)	18,000

NOTE: Assuming that yearly consumption plus inventory change equals imports plus stockpile disposals plus production and that all exports were scrap, i.e., 20,500 + 1,860 = 7,500 + 1,485 + Production.

Source: U.S. Bureau of Mines, Commodity Data Summaries, 1975, pp. 176-177.

Standard practice is to process the ore, rutile, with more than 90 percent coming from Australia. Once again, imports seem constraining. However, United States use of rutile in 1974 was 280,000 ST and about 86 percent was used in paint. Thus, at maximum only about 39,000 ST was used for titanium metal production. If it is possible to substitute in the use of paint, or in the inputs used in paint production, sufficient additional rutile could be made available for metal production. It also turns out that, while rutile is the preferred mineral for sponge production in the United States, ilmenite also can be used, and 99 percent of ilmenite now goes into paint. In 1974, the nation produced 764,000 ST of ilmenite (813,000 ST in 1973) and used 1,050,000 ST with most of the imports from Canada, a secure source.[26] Furthermore, much additional ilmenite and lesser titanium bearing deposits are available within the United States. In recent peacetime years they have not been economically competitive with Canadian and other offshore production. The drop between 1973 and 1974 in ilmenite production is an indication of this. It should have been easy to regain 1973 production levels in 1975 if needed for war.

The 135,000 ST of rutile in inventories should be sufficient to allow a transition from paint to sponge production since it is about one and one-half years of wartime use for metal production. Existing inventories of ilmenite also are available to maintain paint production. The important underlying facts are that only a small fraction of titanium oxide production goes into sponge, that there are very large titan-

ium oxide production capabilities in North America, and that titanium oxide from whatever source is highly substitutable. In addition, it is easy to substitute in paint use; much use is discretionary between years. This fact is partially indicated by the the INFORUM results which show paint demand down some $100M (3%) in 1975 from 1974. In summary, through substitution sufficient titanium ore is available.

Increasing titanium sponge capacity may be more difficult. The ore is extracted by magnesium or sodium reduction, melted, and electrolytically refined in a vacuum vessel to remove contaminants.[27] These materials, the equipment, and the electricity are quite common since they are like those used to refine other metals. Furthermore, because United States sponge plants employed only about 950 workers during 1974, it should be easy to expand the labor force two or three-fold in a few months. It neither is a high skill business nor requires continual supervision by highly trained professionals. Purposeful administration may be needed to achieve the required response time but the input factors are not lacking. Nor is production facilities expansion a problem because the disposable income cut would free substantial construction capacity.

The standard analysis by the FPA yield a titanium stockpile requirement; this differs from the conclusion reached here because this study searches out substitution possibilities. However, the analysis of how to do this and the administrative mechanism to effect this substitution need to be developed before the war. It is likely that this would cost

less than the FPA would propose for stockpiling. For example, the September, 1977 stockpile goal for titanium sponge was 131,503 ST with 27,853 ST on hand. To reach the goal would cost $648M, using 1977 prices.[28] The carrying costs of obsolescence, administration, and the opportunity cost of the funds involved in the stockpiling option make it expensive. At a 15 percent interest rate, a rate at which funds have recently been borrowed to cover the Federal deficit, each year's capital carrying cost on the increment to obtain the goal is nearly $100M and the opportunity cost of present federal stockpiles another $20M.

While not all costs of wartime substitution have been assessed, a case has been made that much substitution capability exists, and that to maintain the needed administrative capability to substitute may cost less annually than present stockpiling.

Closely associated with the availability of raw materials is the availability of stock items which are the typical next step along the production path. Of particular attention for aircraft production are titanium forgings and many types of aluminum and steel mill shapes. The alarm often voiced over the availability of these items is commonly expressed in leadtime terms. Table 29 reflects the lead times for these items as of late 1974, the base period for the INFORUM scenario. These 1974 numbers seem to make it clear that production of incremental aircraft beyond those already in process would be difficult. For example, waiting 52 weeks for an aluminum forging in itself would make timely production

impossible. The second column shows a substantially different picture -- now the same forging can be received in 16 weeks. Other stock items reflect this same wide variation. Obviously the controlling varible is not actual production thruput time, instead the controlling factor is where an item is on the producer's order book. When demand is slack items are received sooner. Thus, the data on Table 29, when interpreted in the light of the wartime ability of the government to displace some defense orders on the order book, would ensure leadtimes at least no longer than those shown in the second column. Actually times much shorter than this are possible if forge capacity is carefully scheduled to facilitate output and the level of civilian output controlled.*

This same sort of solution is evident for the next aircraft input factor considered, machine tools. The INFORUM results in Chapter III showed that there would not be a particularly large increase in demand for this sector if the demand-shift type of manipulation done with INFORUM were instituted in a war. The availability of machine tools for such diversion was demonstrated further in the examination of Pratt & Whitney's aircraft engine building capability. This in itself is probably enough to meet wartime needs, but because this was such a serious bottleneck in World War II, and because some machine tools are highly specialized and utilized, this will be probed further.

*Discussion with operators at the Air Force owned ALCOA operated 50,000 ton forge in Cleveland reveals that production in peacetime is a series of small batches with attendant delay between batches as the new requirements are set up.

Table 29. LEADTIMES FOR SELECTED STOCK ITEMS
(WEEKS)

Item	1974 Leadtime[1]	1972 Leadtime[2]
ALUMINUM		
sheet	49	9
plate	52	9
forgings	52	16
castings	26	10
close tolerance skins	45	15
TITANIUM		
billet	50	NA[3]
forgings	80	NA
extrusions	80	NA
STEEL		
plate	50[4]	10
forgings	50	-
sheet	38	7
castings	26	14
extrusions	42	16

Notes: 1. September for aluminum and steel, December for titanium.
2. April
3. Not available.
4. Shipbuilding reported 20-24 weeks.

Sources: Kane, John C., "Materials Shortage," Presentation on Behalf of the Aerospace Industries Association to the DOD Materials Shortage Workshop, January 15, 1975 pp. 8, 14, 20; Hood, Edivin M. "Shipbuilding Industry Experiences with Material Shortages," DOD Materials Workshop, January, 1975 p.10.

Much more output can be obtained from machine tools with more efficient scheduling. A well known study by the largest of the United States machine tool builders, Cincinnati MILACRON, found that on average 95 percent of the time a workpiece was in the shop it was either waiting or being moved. Of the 5 percent of time on the machine, 70 percent was positioning, loading, measuring, idle, etc. Only 30 percent of on-machine time was typically cutting time.[29] Positioning and measuring time are needed, but there is potential to create cutting time by increased efficiencies in some 70 percent of machine time. Chapter VI explores

impending technological changes which exploit such potential.

This Cincinnati MILACRON study also strikingly documents the fact that items in process are not the bottleneck in the metal working business. The system is not drawn taut with essentially continuous operations being performed on work stock. This is not to imply that moving time is not needed or that all waiting time could eliminated. For example, time spent waiting may also be spent cooling the part. Nevertheless, there is considerable potential for increasing production flow at least temporarily at bottleneck periods and significantly boosting overall output.

In addition to using present machine tools more efficiently there is substantial potential to produce additional machine tools. This production is itself buffered by substantial inventories. At the end of 1974 the industry had $223.8M in finished product inventory, about 15 percent of yearly shipments. Furthermore, there was $678M of work-in-process inventories, another 45 percent of yearly shipments.[30] Even the most complex machining center takes only two or three months to position in a factory in peacetime, so these machines can be useful during the first year.

American builders also produce large numbers of machine tools for export, $537M in 1975 while $317M were imported. Thus, approximately another 15 percent (net exports) of yearly shipments are potentially divertable to defense use.

In addition to these sources of new machines, in the mid-1970s the United States had about 23,500 idle machine tools

held by the Defense Industrial Plant Equipment Center in a general reserve and approximately 34,000 more in Plant Equipment Packages. They are held for IPP and for ongoing production programs.[31] The evidence in this study shows that there is no need to retain any of these tools solely for IPP in the scenario studied. Higher operating rates on present equipment in defense plants, greater use of equipment now installed in non-defense plants, use of machine tool builder inventories and diversion of exports provide sufficient potential.

It is suspected that defense producers are more prone to use special purpose tooling than is industry in general, so this input is now examined. Defense goods perhaps are more likely to push the state of the art in performance and are often distinctively different from civilian goods. Also, they are developed in a bilateral monopoly market, often substantially different from most other goods. For example, in the 1970s at least, many of these items were produced in relatively small quantities, i.e., in hundreds or thousands rather than in mass production millions or hundreds of thousands. This promotes a research and development-like prepossession with "soft" tooling which may yield long production thruput time. At the same time it may increase the ability to quickly transfer production to a different item.

The INFORUM sectors particularly related to special tooling are Other Metalworking Machines and Machine Shop Products (identified as potential problems in Chapter III). Both sell

a significant amount of intermediate goods to an extremely wide range of sectors, 98 and 65 respectively, including many defense producers. In both cases, intermediate goods usage is up in 1975 and investment final sales down with net total sales up approximately 15 percent to about $6 billion. Neither sector exports much, with seven and less than 1 percent of sales, respectively, going overseas in 1974.

Machine Shop Products recorded a 40 percent boost in sales to Aircraft and a 78 percent increase in sales to Aircraft Engines, documenting the large proportion of military sales to Aircraft. (Table 12 showed sales to airlines, nondefense federal, exports, and most intermediate goods buyers down in 1975 from 1974.) Thus, sectorial growth was in the shops producing military items. Fortunately, machine shop capacity tends to be highly substitutable; many shops have a wide variety of machines and produce a diverse set of products. Therefore, domestic consumption capacity could be easily transferred to defense goods. Overall, there is little doubt that the Machine Shop Products sector could have provided the indicated increase in output in 1975.

Other Metalworking Machines, is somewhat similar. Total sales are up less than one percent in 1975 with a decrease of about 24 percent in shipments to capital equipment buyers and a small absolute amount (and share) sold directly to Defense. However, many defense producers are intermediate goods buyers of this sector's output and many of these have significantly increased purchases in 1975 (Table 30). All of these sectors, except Electrical Measuring Instruments, are on the

large percentage increase sector list (Table 8) and four also made the absolute increase list (Table 5). All are on the defense producer list, Table 10. The other 90 sectors using the intermediate goods produced in this sector and the non-defense final use buyers curtailed purchases considerably.

TABLE 30. DEFENSE BUYERS OF OTHER METALWORKING MACHINES ($72M)

Buyer	1974-1975 Absolute Increase	1974-1975 Absolute Increase
Guided Missiles	11.1	63
Ammunition	11.4	98
Other Ordnance	18.9	88
Aircraft	11.6	37
Aircraft Engines	102.7	74
Aircraft Eqpt.	58.7	42
Shipbuilding	32.6	53
Comm. Eqpt.	50.5	61
Electrical Measuring Instr.	1.1	10
Engineering & Scientific Instr.	3.4	15
Defense	50.5	139

Source: 8 January 1977, INFORUM run.

This small sector produces an exceptionally wide variety of products. This is a potential source of widespread stress in a mobilization since so many sectors depend on the output if they are heavy indirect producers for defense (Defense plus the sectors in Table 10 only take fifteen percent of output, as it is not clear that this occurs). The largest of the sector's subsectors is tools and dies, with about 60 percent of sectorial output. This subsector was seen by many as the heart of the United States production performance of World War II. In recent years the productivity of the sector has become suspect, for example:

> "One manager claimed that productivity had eroded to the point where 15,000 hours were required to build tooling in 1974 that was constructed with

> 12,000 hours in 1958. Another stated that a job which required 1,000 hours ten years ago presently would take over 2,000 hours."[32]

Tool, die, and mold making are some of the few activities in modern manufacturing where there has not been a general substitution of machines for labor skills. This activity is often seen as the root of diversity in corporate strategies for managing and capitalizing labor skills and production technology. These sources tend to proliferate designs and to specialize equipment and thus afford a reservoir of alternative ways to perform specific functions, including ones which are quicker. However, this is a high skill, labor intensive industry with skills unlikely to be quickly teachable in an ETA-type program.

For the war size used in INFORUM the possibility exists to satisfy first year defense needs from this sector by curtailing exports, using up inventories and trenching support of personal consumption. However, the industry's products are so diverse and diffused throughout the economy and generally so skilled labor intensive that more data collection and study are needed. The standard industrial practice of retaining dies for years after an item has been produced (including for defense) provides an additional, and difficult to calculate, hedge for a wartime surge. It also is an additional very important reason for selecting weapons that already had been in full scale production at the war's beginning. While the conclusion reached here for this subsector is somewhat tentative, its validity is strengthened by the findings regarding incipient technological change

uncovered in Chapter VI.

The last of the inputs to be assessed in this chapter is special tooling and test equipment. These are more likely to be bottlenecks than workpieces or machine tools because they are more specialized. Test equipment is regularly produced solely to ensure that military goods fulfill contract specifications. This appears to be an area in which the rigidity of military specifications might seriously impair the responsiveness of the production process. Testing appears to create substantial delay, even in peacetime, with the equipment available. An aggregate sector which produces this type of equipment, Engineering and Scientific Instruments was indicated as a large percentage increase (33.5%) sector on Table 6. The INFORUM output shows that the increase in defense final demand for this sector was slightly larger than the increase in total sectorial output. Furthermore, Defense took 44 percent of sectorial total sales in 1975 compared with about 25 percent in 1974 (see Table 10). Note on Table 31 that this relatively small sector has a pattern of sales which makes it a potential problem. The tax program used in INFORUM has already reduced sales to the 29 capital equipment buying sectors by 7 percent and a large reduction in inventories is indicated. It appears that elimination of exports and a severe reduction of state, local, and non-defense federal spending is needed to free aggregate capacity to shift to defense. Perhaps Capital Equipment could be cut further because it probably uses goods more like Defense. However, intermediate goods output is distributed over many

sectors not oriented toward defense-type goods and to indirect support of Defense. Additionally, it is likely that some instruments used in basic research could be diverted to obtain immediately needed weapons production and maintenance instrumentation. This is consistent with the choice to produce only developed weapon systems. If the absolute change criterion is ascribed to, the fact that this sector's output is small and sold to many buyers indicates that it is not likely to cause strategic failure. The percentage change viewpoint, on the other hand, might find this a sector with potential to create many production bottlenecks.

TABLE 31. BUYERS OF ENGINEERING AND SCIENTIFIC INSTRUMENTS ($72M)

Buyer	1974	1975	Change	% Change
Inter. Goods	113.3	146.9	33.6	30
Capital Eqpt	230.9	214.4	-16.5	-7
Defense	243.0	580.9	337.9	139
Non-Def. Fed.	114.6	115.3	.7	1
S&L Education	23.6	24.1	.5	2
S&L Health	136.8	141.0	4.2	3
S&L Safety	15.2	12.8	-2.4	-16
S&L Other	24.9	29.9	5.0	20
Inven. Change	-38.3	-108.4	-70.1	-183
Exports	156.7	198.0	41.3	26
Imports	-33.5	-36.9	-6.4	-19
FINAL DEMAND	643.0	956.6	313.6	49
TOTAL SALES	987.2	1317.9	330.7	33

Source: INFORUM run 8 January 1977.

Two other sectors in the test equipment business are Electrical Measuring Instruments and Mechanical Measuring Devices. The latter was indicated as an input to Aircraft Engines on Table 20. Both have small increases in total sales and a much smaller percentage of output going to Defense than did Engineering and Scientific Instruments.

This was seen in Table 10 for the Electrical Measuring Instruments sector. Each also had less inventory drawdown and a much larger amount possibly divertable from exports. These sectors do not appear likely to contain important constraints without IPP.

A summary of the findings in this chapter regarding the long list of inputs to aircraft manufacturing follows. First, it was discovered that the most quickly substitutable general asset, inventory, has tended to be in greater supply as the economy grew in the period leading up to 1975. This becomes more apparent as attention is focused more closely on the aircraft industry. The trend is stronger in materials and goods-in-process than in finished products and is true in both inflation adjusted and sales volume terms. The implication of this trend is that opportunities for substitution using private sector resources to meet emergency needs are increasing and therefore less spending on present federal stockpiling and IPP programs are necessary.

The second input was industrial facilities. The World War II record indicates that plants can quickly be built or converted from other pursuits. In addition, a recent DOD study indicates much excess capacity in present defense plants. The main insight is that facilities are very easy to put to alternative use.

The third input, labor, is more complex. The World War II record shows that much more output was achieved with more intensive and extensive labor employment than had been believed possible. However, labor markets in the 1970s are

much tighter than they were at the beginning of World War II. Nevertheless, the main finding is that with aggressive government action to discourage production in non-defense industry and to encourage movement to aircraft producers that production goals could be reached. The overall effort would probably need to include additional training in industrial skills using short programs like those developed by the ETA during the early 1970s. To orchestrate the rapid government action would likely require preparedness planning to insure the administrative capacity. This is substantially different from existing preparedness planning. The labor input is particularly important because labor is inherently highly substitutable for shortages in other inputs.

Next, the diffcult aircraft engine input which had been identified in Chapter III as a high stress sector was assessed in more detail. This is a case where demand shifting from civilian production is particularly important. It also is a sector requiring numerous individual parts, materials, labor skills, etc. Through detailed examination of the Pratt and Whitney case, a way was sketched in which this important input's production goal could be attained. It was clear from this that it would not be easy. At a minimum, a six-day week for present workers, the creation of a second complete six-day shift, and diversion of two-thirds of present sectorial civilian production were needed. This would entail drawing upon many new suppliers and subcontractors, ETA type training programs and perhaps some increase in overall productivity from better motivation of workers. Further

increases would be possible from adopting a three shift operation. This finding regarding aircraft engine production is much different from the conventional wisdom which is much like that of pre-World War II experts who maintained that the production rates that were attained in that war were unachievable. The underlying essential ingredients are to have a clear production goal that includes a time dimension and to take extensive advantage of the myriad opportunities for substitution in achieving such a goal. Peacetime business-as-usual does not do this.

A similar finding in the case of materials inputs was next reached with titanium used as an illustrative difficult material. Here the problem is substantially easier because of the much smaller size of the industry, but once again, strong, prompt government action is needed. The closely related input of industrial stocks were found with similar but even lesser problems. The capacity to make these forgings, castings, etc., were found to be largely preempted by civilian production in peacetime. Dramatic improvements in leadtimes can be expected in wartime by affording defense goods absolute priority.

Next, attention was given to increases in machine tool availability for defense production. It was found that much time on typical machine tools is not spent cutting, even during active shifts. More efficiency in the scheduling of jobs, particularly in using larger batches, can provide much more effective capacity. In addition, there are large additional inputs possible from new production by diverting

exports and pushing inventories forward to users. The summary finding was that these sources, plus the uses of tools in present non-defense plants, yield no reason to continue to retain present federal machine tool reserves for IPP. The closely related Machine Shop Products and Other Metal Working Machines were also not found as serious problems. Possible exceptions uncovered were specialized tools and dies and engineering and scientific test equipment. Even in these two small related subsectors it did not appear probable that IPMs would be needed. The fact that non-defense research and production can be curtailed along with defense research provides a good chance that these would not become unsurmountable wartime constraints.

This examination of the Aircraft sector has shown that industry has far more capability for rapid production of aircraft, including engines, than is generally supposed if substitution opportunities are aggressively pursued. This is for a sector which is likely to be both vital militarily and extraordinarily stressed in production. This example shows in summary that the United States is large enough and can have enough time elasticity to produce the requisite military aircraft within one year. To do so, foreign sales, civil aircraft production, and labor and machine capacity from other civilian production must be substituted. For some inputs second, and possibly third, shifts may be needed.

This chapter has sifted from large sectorial aggregates to the tools, equipment, materials, labor, etc. used as

inputs in aircraft manufacture. The weight of the evidence in answering the chapter's central question is that substitution possibilities abound. As disaggregation proceeds it becomes easier to finitely appraise substitutes because there always is a function to be performed, and tooling, materials, etc., shortages cannot be evaluated without understanding the alternate functions satisfied by the same factor.

At a few junctures a need for some type of preparedness planning that determines the nature of substitution possibilities and that creates the requisite administrative ability was found. The most important administrative capacity needed is the ability and willingness to intervene quickly in commercial markets to force the national defense need ahead of unrelated domestic commerce. From a theoretical point of view, this intervention might take the form of government, or government contractors, only bidding needed materials, production capacity, and labor away from non-defense pursuits. Practically, however, this could be vitiated by suppliers protection of long-term commercial relationships and by speculation against later wartime needs. The main point, however, is that this type of analysis can make viable a substantially different type of preparedness planning based on substitution. This conclusion could not be reached solely with the INFORUM analysis; the model does not contain the detail really needed to assess potential bottlenecks in supply.

V. LIMITATIONS OF RESULTS

This chapter is concerned with the limitations of present economic and industrial data and of input-output models that might significantly bias the insights of previous chapters. Could they cause that assessment to seriously misjudge the wartime production potential of the nation? If so, in what direction might the INFORUM analysis and the non-INFORUM peacetime supply data be biased? In this context, recall that overall peacetime defense spending is between five and six percent of GNP and materiel procurement is less than half of that. The defense effort in this analysis is therefore an increase to about twelve percent of pre-war GNP. Are there reasons to believe that such a structural shift would be so far from peacetime experience that the analysis would be seriously in error? For example, if defense goods producers are pushed far from peacetime norms perhaps diminishing returns would necessitate curtailment of much more civilian activity than appeared necessary above. Alternatively, if defense firms operate in regions of increasing returns, or can quickly achieve increasing returns to scale in wartime, then the results above may show more need for substitutability analysis than is really essential.

The major potential limitation sources addressed in this chapter are input-output models (INFORUM in particular), capacity definition and measurement, and X-inefficiency. While the measurement error in each or any of these is pertinent to this discussion it is not its major thrust. There is a presumption that error in observation is both relatively

small and unbiased. Instead, what is examined here are possible sources of major error which result from economic conventions, definitions, and data collection practices.

INFORUM has been built for forecasting during relatively non-dichotomous peacetime situations. The focus here is on the transition to a war economy, i.e., into a dramatically different economic world. At this juncture the twin engines of government mandate and non-governmental behavioral shifts may make input-output analysis using pre-war coefficients extraordinarily unprecise. Surprisingly little attention has been given to this in the literature, however, except to confirm that unascertainable conditions peculiar to a war economy affect the input coefficients.[1] Suggested reasons are drastic changes in product mix, factor shortages, abnormally large investment in some sectors, and wartime observation errors. These are consistent with Marshall's observations on war periods (Chapter II).

There are two areas of concern about the use of the model in this study, the intrinsic characteristics of the model and its data base and the way in which the model was exercised. The latter point centers on whether the duration of the conflict has been satisfactorily encompassed, on whether unusual cyclical phenomena attended 1974 and 1975, and on whether the factor changes used to induce low unemployment rates were complete enough. Additionally, there is the major concern expressed in Chapter III about scaling up the entire Defense vector. Large shifts in the defense output mix might be needed and the model might have been used to

closer approximate such conditions. These reservations on the model's use are worthy of consideration; however, attention here is upon the first point, the usefulness of input-output in dealing with the transition to war conditions.

A very general concern with input-output models is that they do not include variables which reflect behavior. This appears extraordinary because such models are used regularly to examine possible alternatives at times of large market change. For example, the energy "crisis" prompted many of these studies. This study is of the same sort. One soon realizes that input-output reflects the paucity of attention to behavioral factors generally paid by economics. The possible impact of this is examined further later in this chapter.

Another broad, and related, concern is that substitution considerations are not intrinsic to such models, let alone the speed of substitution. In fact, in assuming temporal stability of coefficients, input-output economists generally deny a distinction between technological change and substitution. This restriction is inappropriate to study of preparedness planning because history shows (see the Historical Appendix) that during a war innumerable substitution opportunities are found and exploited. As a result, this inquiry has probed subsectorial substitution possibilities outside of INFORUM, particularly on the supply side. Both substitution and technological effects are reflected in peacetime coefficient changes and both are usually small. In

wartime both change faster, with substitution likely to be much more rapid. In wartime, coefficients would be under the most pressure for change in the war materials area. The ability to substitute quickly and the pace of adapting technological change would both be important. In addition, technological change is also driven by behavioral factors; it encompasses the substitutability of factors with both old and prospective technology. Technological change is examined in Chapter VI.

Even if input-output models now included behavioral factors and were sensitive to the time needed to complete series of substitutions, the data to support them are not available. Input-output analysis and preparedness planning are captive to the practices of data collectors; yearly data are collected, so yearly accounting periods are analyzed. This may be a reasonable first choice because some industries, e.g., agriculture and fuels, are affected by seasonal factors which average out over a yearly cycle.* Other industries might be more usefully studied using other cycles. For example, the machine tool or business construction industries might be

*Even with agriculture the validity of intersectorial coefficients based on yearly data is called into question because of problems in correctly allocating input stocks, particularly capital, to output flows. Ideally, the flow of capital services is what should be allocated. Differences in shift and/or seasonal usage of inputs leads to mismeasurement of sectorial factor proportions. For a demonstration of the impact of this problem see G.C. Winston, "On Measuring Factor Proportions in Industries with Different Seasonal and Shift Patterns or Did the Leontief Paradox Ever Exist?" Economic Journal, December, 1979, pp. 897-904. Understanding variations in input proportions across shifts and seasons is important for preparedness analysis; it strikes at the heart of capacity determination.

geared to cycles longer than a year, and electronics, which today generates completely new technologies in about six months, to a shorter period. Even if exact annual average input-output relationships for the wartime production process are known, they are not complete enough for calculating all inputs to produce specific numbers of a weapon by a given date. To derive accurate input-output coefficients for wartime, the length of the production cycle for intermediate goods and the number of cycles in the accounting period need to be assessed to create a time-phased road map of the total production process of each vital weapon. As was demonstrated in Chapters III and IV, this tracing of indirect effects for even one weapon can involve parts of many, if not most, of the conventional input-output sectors.

Another limitation of input-output models is the area of coverage. Usually a nation is covered, although there is a trend toward interacting national models. This trend is particularly useful for defense economics since high technology goods, especially components and critical raw materials, move increasingly in foreign trade. This makes availability assessment by defense planners much more difficult. High technology components produced by multinational corporations particularly complicate the picture in that they are difficult for defense planners to trace. Foreign production also means that planners must guard against interruptions of overseas supply. Another facet of the area of coverage problem is that for some mobilization questions it is useful to have less than national models. For example, in assessing the

ability of Pratt & Whitney to produce military aircraft engines, coverage of the area from which the firms draw inputs is pertinent. However, data for market areas are rarely collected. Some Census data are by geographic region or by state, but none relates to the market area for individual products.

A major limitation to input-output is the method of sectorial aggregation. Wide choice in aggregating is possible because dollar values are used rather than physical quantities. Dollar values are used for such reasons as difficulty in defining physical output units for services and in collecting appropriate data.[3] While present establishment and activity aggregations were substantially based upon substitutability driven by money price changes when they were created, this changes with time as product lines diversify. Moreover, sectorial aggregations do not capture a significant part of many industries. For example, in 1972 the specialization ratio was .86 for Aircraft, .87 for Aircraft Engines, and only .77 for Aircraft Equipment. In addition, usually present classifications are based more upon product grouping than upon production process. Therefore, technological and factor market changes do not affect the activities of each firm in an "industry" in the same manner.

As the economy increases in size and other large firms enter a product field, particularly by absorbing small firms that produce subsystems and components, the specialization ratio is likely to decrease, meaning that sectorial data using present definitions will become less instructive. At

the same time, industries tend to become less descriptive of specialized products as the division of labor increases. The trend toward larger corporate entities should make formal IPP and stockpiling less necessary as fewer private firms need to be dealt with for defense production. Concomitantly, less specialization within firms makes intrafirm tracing of component and indirect inputs more difficult. The planning problem could be eased by disaggregating sectors into narrower classifications as product lines and production processes become more diverse. Recent efforts to improve input-output coefficients have taken the opposite approach of redefining secondary products so that they remain in the producing sector rather than being credited as sales to sectors in which these products are primary.[5]

This approach will make sectorial aggregations even more diffuse and the resulting coefficients more sensitive to changes in market structure and less driven by central technological relationships. Input-output thus becomes less useful to preparedness planning as aggregations encompass more substitution opportunities as technology evolves. With continual development of new products and factor uses, there needs to be continuing detailed study of structural change and resulting reaggregation. Each choice of sectorial aggregation yields a different solution of total and indirect demands. Furthermore, the more aggregate the input data used, the less ability there is to isolate input associations with particular intermediate or final goods. Kapp and Smith have recently found substantial distortion of input associ-

ations if inputs are improperly aggregated.[6] This study maintains that with time, aggregate sectors increasingly mask the actual combination of inputs in products. Thus, there is potential for much more production of selected items than input-output coefficients indicate.

Ideally, for preparedness analysis the data collected for input-output should allow isolation of inputs by function so that timely substitution potential can be more accurately assessed. For example, silver in tableware performs a different function than in photography or than in the electrical circuits of an ICBM. A useful approach to this would be to collect data by product not by producing sector which is the standard United States approach. This should help in identifying inputs to products. The USSR conventionally does this.[7] As far as preparedness planning is concerned, this could lead to the reinstatement of the use of bills of materials for defense goods and related intermediate products -- a practice which has been dropped since World War II.

In summary, there are substantial reservations with the use of any input-output model for preparedness planning. Problems in how substitution and behavioral efforts can be considered as well as concern with the usefulness of data reflecting conventional accounting periods, areas of coverage, and methods of sectorial aggregation exist. The effect of such factors are reflected when attempts are made to assess the accuracy of present calculations by comparison with the results from other input-output models.

One such comparison projected final defense demand for

five sectors for eight years using INFORUM and FPA data and compared the result to FPA projections. An _average_ absolute difference for forty comparisons (5 sectors for 8 years) of 30.4 percent was found. The largest difference of the Aircraft and Aircraft parts sector was 15.9 percent. A comparison was also made between FPA and Department of Defense (MA-175) sectorial requirements and BEA published numbers for 1967. The FPA projection of Aircraft and Aircraft Parts was 32.0 percent larger than that of BEA; the MA-175 results were even larger, 58.8 percent.[8] INFORM uses MA-175 data, so the aircraft industry demand forecast using INFORM may be unnecessarily large. Nevertheless, the work above indicates that substitutions could make the needed supply available.

If differences between peacetime projections are as large as plus or minus 30 percent, clearly caution is warranted in using results for defense planning. The fact that peacetime projections may be 30 to 60 percent larger than actual peacetime figures indicate reinforces this. In tracing through subsectorial detail in Chapter IV, the same point is addressed; there are many substitution possibilities available that, when exploited, will result in input-output coefficients which are quite different.

INFORUM and most other modern input-output models are not closed systems. Intersectorial demands are projected using broad macroeconomic inputs; capacity within individual plants or sectors is not endogenous.[9] Non-INFORUM subsectorial detail was brought into the inquiry in Chapter IV to help discover if wartime supply could be made to substan-

tially exceed peacetime norms. It turns out that these peacetime capacity norms are vaguely defined and poorly measured. Let us now examine these capacity measures.

This study generally adopts an engineering measure of capacity (24 hours per day, 7 days per week, less maintenance), although it was not necessary to fully employ engineering capacity in the Chapter IV analysis. Even this measure is not the absolute limit of production with given plants. Further gains can be made by increasing the pace of activity by substituting fuel, faster equipment wearout, decreased safety, etc.

Most peacetime industrial operations and preparedness planning are based upon a less comprehensive measure, maximum practical capacity (where marginal physical product is zero, given customary practices).[10] Even using this measure much capacity is idle in peacetime. During the last twenty years, overall United States capacity utilization using this standard has varied from about .7 to a bit more than .9. Aerospace and Miscellaneous Transportation sector capacity utilization was 75.7 and 71.3 percent in 1974 and 1975 respectively.[11] These indicate a potential 40 percent increase in production in 1975 from 1974 if maximum practical capacity were instantaneously attained. If this were all of the increase that could be attained, the results of Chapters III and IV would be seriously challenged and present formal IPP and stockpiling programs might need to be greatly expanded.

Even if this definition of capacity were accepted, there is considerable controversy on how to correctly measure

capacity. Some use a general equilibrium concept that capacity is an "...attainable level of output that can be reached under normal input conditions -- without lengthening accepted working weeks, and allowing for usual vacations and for normal maintenance." This view maintains "...that pre-occupation with measures for individual industries, considered separately from others at the same time, tends to overstate capacity for the system as a whole."[12]

Others take a partial equilibrium view that capacity measures should not be affected by intermediate product shortages.[13] This study ascribes essentially to this second view. Preparedness planners must not concentrate solely on general equilibrium because it will tend to understate capacity in the sectors/subsectors producing vital defense goods. By substituting toward the highest stress points supposed capacity limits can be exceeded. Indeed, even in peacetime, there is significant elasticity between output and maximum practical capacity. Perry found it to be about .25.[14]

In wartime, the amount of capacity increase is likely to be substantially greater as more resources are applied to move closer to, or beyond, engineering capacity. The World War II experience cited in Appendix A documents this. This record is buttressed by numerous reports, such as: "Many plants shortly after being placed in operation, were producing hundreds of percentage points in excess of their rated capacities."[15] A similar, but smaller expansion tendency was exhibited during the Korean and Vietnam Wars as shown on Table 32.

TABLE 32. WARTIME OUTPUT AND CAPACITY

YEAR	OUTPUT	OUTPUT %CHANGE	CAPACITY	CAPACITY %CHANGE	%CAPACITY CHANGE / %OUTPUT CHANGE
1950	20.3	---	54.8	---	---
1951	32.7	61.1	58.4	6.6	.11
1952	52.1	89.9	65.2	11.5	.13
1953	65.3	6.1	72.7	11.5	1.89
1965	75.7	---	90.3	---	---
1966	90.0	20.1	98.9	9.5	.47
1967	99.9	9.9	109.6	10.8	1.09
1968	102.4	2.5	117.7	7.4	2.90

Note: Aerospace and miscellaneous transportation equipment sector outputs and capacities in percent of 1967 output -- average yearly values.
Source: Derived from FRB Measures of Capacity and Capacity Utilization, p. 39.

Note that during the Korean War output jumped by more than 60 percent between 1950 and 1951, a period more like a mobilization than 1965-66 when production rose only 20 percent. Next, note that changes in capacity and output are positively related, although not constant. The first war year results are mixed, one is larger than Perry's .25 and the other is smaller. Third, the size of the increase in capacity and of the capacity/output ratio after about two years is impressive. Fourth, the capacity change per unit of output change was both larger and quicker in the Vietnam War than in the Korean War. This could be evidence of increasing resilience in the United States economy as new manufacturing technology had been introduced in this sector. The potential for increased resilience is examined further in Chapter VI.

This analysis of capacity data shows that planners realistically are justified in discarding the capacity limits derived from peacetime data; in wartime they can quickly be

substantially exceeded. Care should be given to the capacity definition used and to the method with which utilization rates are measured. These results show that INFORUM calculations might substantially understate actual production potential and are supportive of the Chapter IV findings that the postulated scenario could be supported in time.

The ability to surpass supposed peacetime capacity is in addition to large increases often possible in merely attaining acknowledged peacetime capacity. Unused, known capacity is particularly evident in military aircraft production. At least during the 1970s, production capability has regularly been built which is unnecessary for the peacetime procurement that has occurred. Funds provided each year during this period have allowed buying fewer of each type of aircraft than originally was planned. And, as numbers purchased decreased the real average cost paid increased, both because of being at a higher point on the average cost curve and because expected learning curve economies were not achieved. Unanticipated inflation tended to curtail unit purchases further.

Unused, acknowledged capacity was likely also built because firms, or the military services, desired a capability for higher peak rates in the event of war or foreign military sales. In addition, firms appear to be reacting to what Winston calls ex ante rhythmic trends over time. Military aircraft sales have been below historic rates since the Vietnam War; a catching up, at least to rates that will sustain present units, might be expected. This sort of

anticipatory overbuilding of capital stock is a common industrial phenomenon, not one restricted to defense production or to the aircraft industry. Winston estimates that even in a year of weak aggregate demand more than 90 percent of manufacturing capital stock idleness is intended.[16] Present government spending on IPP could also be categorized as creating idle capacity in anticipation of long cycle rhythmic trends over time.

The evidence here is not wholly supportive of the hypothesis of Chapter I; the capacity/output increases found during the first year of the Korean and Vietnam Wars are insufficient to satisfy the scenario under examination here. However, the efforts in Korea and Vietnam were not full-scale mobilizations like World War II with as much attendant behavorial change, the subject to which we now turn.

There has long been a realization that economic inquiry, and input-output analysis in particular, must include behavioral insights, perhaps from other disciplines. Leontief is on the mark:

> "In analyzing the changing structure...we must get our information from the technical literature, from ironmasters and from rolling mill managers. To study the changing pattern of consumer behavior, we have to develop practical cooperation with psychologists and sociologists."[17]

This insight presages several important related economic ideas, Leibenstein's probing of the motivational roots of economic agents' behavior, the learning-by-doing literature (see Chapter II), and the potential of manufacturing technology initiatives (see Chapter VI).

This call is still to be satsified, even for analysis of peacetime price changes. As Fisher reflects:

> "Clearly one cannot hope to have an adequate treatment of the problem without dealing with the process by which prices adjust. Unfortunately we lack an adequate understanding of this central issue...when one seeks to discover more structure in the price-adjustment process, that device fails, for it is hard to gain much insight into adjustment rules based on nobody's behavior."[18]

There is no doubt that there will be large changes in behavior in wartime which will dramatically affect defense production, changes larger than those underlying peacetime data. It is also unlikely that the effects of these changes will all be transmitted by prices because the nation will use price controls to prevent inequities. Additionally, government allocation of defense-important goods and inputs can be expected. Now, as postulated in Chapter II, the time dimension becomes much more important. At the same time, the effort put forth by economic agents becomes more dominant. Even in a planned economy these effects are important; this realization seems to be spreading within peacetime planned economies.[19]

In the United States, Leibenstein has been a leader in the effort to bring behavorial effects into economics. In particular, he sees the forces of habit and custom as a substantial impediment to production.[20] Leibenstein's relatively deterministic theory based on motivation and the resulting effort expended by economic agents is significantly supportive of this study's hypothesis. His work encompasses rapid institutional and technological change which can be

expected in a wartime mobilization (although he does not relate the idea to wartime). In addition, the theory reflects the idea that economic activity is driven by more than the physical characteristics of goods and money prices. In the present context this is characterized as multi-dimensional goods as defined in Chapter II.[21]

The empirical evidence of the X-efficiency literature clearly indicates that motivation is a factor which could significantly bias the results of Chapters III and IV. For example, Bergsman found X-efficiency plus monopoly returns for a number of countries of 2 to 7 percent of GNP, with 7 percent for Brazil.[22] Seven percent of GNP would be highly significant relative to this study's hypothesis; it is larger than the postulated 1974 to 1975 increase in GNP. More important, it is about as large as the increased percentage of GNP taken by defense spending in this scenario. Is it possible that such a large and rapid increase in productivity could be forthcoming in the United States? *A priori* this might seem implausible. However, the United States is a mature economy with many old industrial facilities and highly subdivided, large industrial firms. It is possible that present high levels of productivity per manufacturing worker stem from much human and physical capital per capita which mask substantial X-inefficiency.

The X-efficiency of firms is highly relevant to this study, particularly considering the way that INFORUM was exercised. Recall (Table 3) that there was little increase in GNP and a 139 percent increase in defense demand.

Leibenstein cites data for firms in developing nations and in the United States and the United Kingdom. Increases ranging from 7.5 percent up to 291 percent were reported from first line case histories. These results were sustained over a period of study. Most cases showed increases between 43 and 76 percent.[23] If such gains could be attained from defense suppliers, the INFORUM derived demands above could be satisfied with much less substitution than indicated as available in Chapter IV.

Some observers of peacetime weapons procurement believe that defense industries are the least production efficient of United States industries.[24] If this is true, then there are exceptional opportunities to increase X-efficiency and reduce resource and time cost. A war that prompted increases in output per worker like the high end of the range (291%) would need no IPP for a stress like that used in INFORUM. On the other hand, this dramatic surge could not occur unless all indirect support was available. Some, notably metal ores, come from highly civilian-market-oriented firms which operate under much more competitive circumstances and are perhaps less likely to be highly X-inefficient. Likewise, as noted in Chapter III some metal ores used as alloys are largely imported. However, recall that inputs nearer the beginning of the production process are generally the most substitutable.

Additional evidence in support of the existence of much X-inefficiency come from disparate sources. For example, Rees has found that there are very large differences in the

productivity of establishments in the same four-digit SIC industry.[25] This is thoroughly consistent with the existence of much habit and custom as well as the brake of sunk physical and human capital.

History also provides evidence in support of this motivational factor. As DeTocqueville noted long ago:

> "Hence it is that the selfsame democratic nations which are so reluctant to engage in hostilities, sometimes perform prodigious achievements when once they have taken the field."[26]

It is possible that a democratic society is particularly likely to generate X-inefficiency, at least in defense production. A custom has developed in defense production that allows free use of government owned plant and equipment plus progress payments; this surely produces some inefficiency. A financial rescue such as that of Lockheed Aircraft likely promotes inefficiencies also.

The World War II data in the appendix seem to show that substantial X-inefficiency was overcome during that war, that the bounds of previous activity were burst. This is reflected in some input-output work of those days where it was found "...that very little of the instability in the coefficients from World War II data seem to be attributable to technological change or to new products."[27] In addition to the effect of price shifts, it is likely that coefficient change resulted from motivational changes that yielded procedural adjustment, more individual effort, use of new suppliers, reduction of labor discrimination, and more rapid introduction of new technology. Some of these institutional

constraints are regularly considered fixed, even in dynamic analysis. In Marshallian terms, the previous long run may be approached much more quickly in a war and new long run norms established. Since World War II, trends have been toward more stages of production and less perfect competition. With a presumption that habit and custom have more force in less competitive markets there may be an impetus toward more stable peacetime input-output coefficients and less X-efficiency. At the same time, this makes these coefficients less likely to be useful in forecasting wartime potential. Input-output and other models with no endogenous attempt to assess behavioral dynamics can project only the peacetime habits and customs of the recent past.

Leibenstein is not the only one to show X-inefficiency. It is increasingly clear that firms do more than short run profit maximize. This results in great potential for a change in motivation producing quick and large increases in output. The theory of capital utilization demonstrates that it is rational for firms to build and maintain substantial excess capacity for a variety of reasons including rhythmic variations in input prices and in demand and as a market entry deterrent. This stems from the idea that use of the capital stock is an economic variable in the long run.[28]

The learning curve literature (introduced in Chapter II) also strongly supports the thesis that much more can be done with existing resources with motivational changes. The shape of individuals' learning curves is a function of the mental effort required on the job, either because the job is diffi-

cult or the worker inexperienced.[29] The slope of learning curves should become more steep with all workers more highly motivated during a rapid wartime buildup than during peacetime. Importantly, the very experienced ones may be more likely to share "tricks of the trade" with less able workers. This change in behavior would produce increases in output which present learning curves would not predict. These gains are in addition to those to be expected from larger output quantities.

In summary, the evidence is strong that there is substantial X-inefficiency in the modern United States economy. It has been found in the record of other nations, including a NATO ally. Its reduction was a likely source of the production miracles of this country in World War II. Additionally, current United States observations, particularly in defense industries, indicate that there is potential to do much more with present inputs.

This chapter has found serious reservations to the results achievable in preparedness analysis by examining three major subjects, input-output models, capacity measures and X-efficiency evidence. Present input-output models which lack constraints and are driven by peacetime data derived with standard conventions should not be expected to give definitive answers to the preparedness planning problem. It has also found that there are serious definitional ambiguities and measurement problems with production capacity data. These systemically tend to understate the limits of wartime production, potentially by a large amount. The evidence of

X-efficiency further supports these results; the potential exists to produce much more under wartime conditions that prompt behavioral change.

Overall, this chapter finds that these limitations are likely to be substantial. Moreover, the bias caused by these factors could yield a serious understatement of the ability of the nation to mobilize successfully without present formal preparedness planning. The size of such biases is large enough that the results of both chapters III and IV may be too restrictive; the nation may well be able to do even better than those data indicate.

VI. TECHNOLOGICAL AND INSTITUTIONAL CHANGE

Throughout this study the historical record, particularly that of the World War II mobilization, has been used to show that there is more capability for avoiding strategic failure in the economy than the conventional wisdom maintains. There is the possibility that the cumulative effect of technological and associated institutional change since World War II has made that experience completely irrelevant to assessment of present mobilization potential. There is related concern that future technological changes which are now predicted might negate the potential for wartime substitutions uncovered above. This chapter answers these questions.

What is really being probed is the relative efficiency of the United States economy during World War II, the present, and future planning periods.[1] If efficiency has decreased for inputs to defense production, or in the use of defense goods, then more preparedness planning may be necessary, not less. If group and individual effort has eroded over the years as the X-inefficiency literature implies, it is likely that demonstrated peacetime efficiency would have decreased. There are numerous reports that indicate that effort has decreased in industrial sectors. Some of these were cited in Chapter IV. X-inefficiency also implies opportunity costs incurred by unwillingness to adopt new proven technologies.[2] While increased X-inefficiency in peacetime

is not desirable, it creates more potential for a dramatic increase in effort, and therefore in production, in wartime.

The record of the United States economy in World War II makes it clear that secular change since then has substantially altered the size and structure of the economy. One important driving force is that the Federal government has a greatly increased role. For example, government owned equipment and structures rose from $52.8 Billion in 1940, to $228.5 Billion in 1974 (in constant 1972 dollars).[3] Additionally, there now are many more restrictions, such as environmental and safety controls, higher marginal tax rates, and cumulatively more effects from anti-trust and other regulatory provisions, placed upon industry by government. The amount and proportion of GNP moving in international trade has also increased, possibly changing the need for IPP and stockpiling.

There also have been particularly large changes in labor availability. The labor force and its participation rate has grown steadily over the years (Table 5A). At the time of the scenario in this study, participation rate was nearly at the World War II peak and much above the level of 1940. When coupled with an unemployment rate and a proportion of people engaged in agriculture (Table 33) that is much lower today than when the nation entered World War II, today's lack of labor slack for potential allocation to defense is evident. Because labor is such an important input, and conventionally considered highly flexible, this may be a major reason to

doubt that there is enough allocative and adaptive efficiency to react to wartime stresses in a timely way. This industrial shift must occur simultaneously with an armed forces' increase from a strength only about 500 million larger than that of 1941. One might suppose that relatively little of this personpower is likely to come from an increased work week; the work week in manufacturing has been fairly stable for thirty years and is only about thirteen percent below the peak (Table 5A). However, note that a thirteen percent gain in total work hours is sufficient to fulfill all added requirements in this scenario, if the increase can be employed where needed.

TABLE 33. EMPLOYMENT PATTERNS IN SELECTED YEARS (Millions)

YEAR	AGRICULTURE	SERVICE PRODUCING*	MANUFACTURING
1935	10.1	16.2	9.1
1939	9.7	18.3	10.3
1940	9.5	20.2	11.0
1941	9.1	20.6	13.2
1942	9.2	21.7	15.3
1943	9.1	22.4	17.6
1944	8.9	22.6	17.3
1945	8.6	22.9	15.5
1950	7.2	26.7	15.2
1951	6.7	27.9	16.4
1952	6.5	28.7	16.6
1953	6.3	29.2	17.5
1954	6.2	29.3	16.3
1964	4.5	37.4	17.3
1974	3.5	53.7	20.0
1975	3.4	54.4	18.3

* All Services, including government.

SOURCES: Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1970, Part 1, pp. 126, 137. U.S. Department of Commerce, Survey of Current Business, May, 1976, pp. S13-14.

This study posits that the necessary interindustry labor shifts can be accomplished. The INFORUM analysis showed the

intersectorial transfer required if labor productivity did not change. Much labor would have to be shifted within the manufacturing and construction sectors and many people would have to be diverted from service industries. Such a quick shift likely would require stronger measures than the job loss and tax increase approach used in Chapter III. During World War II, some Germans literally were bombed out before they would shift from customary endeavors to war goods production,[4] indicating that adaptive efficiency was significantly less than it could have been. It seems clear that government action would be needed to induce labor to adjust quickly to support a war effort at a level close to actual potential. The first of these actions should be increases in wages in selected plants. However, housing, medical, transportation, and other programs likely would need to follow soon. Government controls on the ability to purchase consumer goods which compete for materials and labor needed in defense goods could be used to induce labor to move quickly to where most needed. Workers in selected defense plants could be given preference in acquiring these scarce goods.

Much increase in labor capability can also be found within present defense production activities. For example, within the aircraft industry there appears to be a substantial potential gain from X-inefficiency reduction. Studies have "...found hard-to-believe low levels of manufacturing efficiency in major aerospace contractor plants."[5] These studies trace some 42 percent of direct costs to labor on

typical production contracts, with half found nonproductive. This is in addition to the prevailing judgment that aerospace firms employ too large a proportion of indirect labor. This implies labor shortages in the aircraft industry might be less severe than the conventional wisdom would indicate. Because this sector produces technologically complex defense products that require more specialization than most sectors, this is fortuitous. During the years since World War II, labor in general has become less homogeneous, thus creating more difficulty in rapid transferring it to other production processes. Nevertheless, labor is still a highly substitutable factor of production because tasks can be subdivided and learned quickly.

Technological change since World War II is at least as much embodied in the capital equipment and inventories used as in the labor. In Chapter IV, real inventory levels in the aircraft industry were found to be increasing with time, both absolutely and in relation to sales. Does this reflect a general trend toward increasing the use of capital in manufacturing since World War II? Such a trend would be consistent with the relative growth of service sector employment. It also should be expected if manufacturing labor is increasingly nonproductive, as found in aerospace above. Table 34 displays the real capital/labor ratio for manufacturing since before World War II.

Note that between 1939 and 1944 the capital stock did not keep pace with the increase in direct labor. This might

TABLE 34. REAL CAPITAL/LABOR RATIO FOR SELECTED YEARS

YEAR	K/L*
1939	4.95
1940	4.69
1941	3.96
1942	3.56
1943	2.72
1944	2.73
1945	3.22
1950	5.07
1951	5.01
1952	5.23
1953	5.18
1954	5.91
1964	7.22
1974	8.53
1975	9.54

*Real equipment and buildings plus net capital services for manufacturers divided by direct manufacturing labor.

SOURCES: U.S. Bureau of the Census, Historical Statistics of the United States Colonial Times to 1970, Part 1, pp. 138, 259.
U.S. Department of Commerce, Survey of Current Business, May, 1976, p. S-14.
U.S. Bureau of the Census, Statistical Abstract of the United States, 1977, p. 467

be expected since much non-defense plant and equipment building was deferred during the War. In contrast, there was no particular trend during the Korean War. The main message of the series is the pronounced capital deepening that has occurred since World War II. In 1974, manufacturing used almost three times as much capital per direct worker as in 1945. The ratio was also some 82 percent higher than the pre-war 1940 baseline. While undoubtedly more of this was pollution control and safety equipment than in the 1940s, nevertheless, it is a large increase. This increase implies that more opportunities now exist for substitution from reapplication of the existing building and equipment stock

since the typically less substitutable factor, capital, is in greater relative abundance. In addition, relaxation of some present evironmental and safety standards is now a more promising way to gain some construction and manufacturing capacity quickly than it was in the 1940s.

This dramatic increase in the capital/labor ratio since World War II shows ever increasing capacity in the machinery and structures in industry. In particular, as seen below, increasingly sophisticated machine tools and other technological advances are likely to continue to be introduced, driving the ratio still higher. This presages an increased substitutability for defense production that is particularly important because older parts of the defense industrial base have atrophied since the Vietnam War.

The fact that added labor does not seem to be as readily available in the mid-1970s as at the beginning of World War II is a significant reservation to the study's findings. This does not, however, make the World War II experience irrevelant; it merely means that more attention should be given to personpower planning today. Furthermore, given much more capital per capita today, there now is a much larger payoff in output to be expected from such attention to labor. The record shows that part of the nation's adjustment to World War II was a reduction of the capital/labor ratio -- the same thing is an indicated approach today (and in effect pursued in the INFORUM analysis by curtailing wartime capital purchases). This substitutes capital goods and work stocks for

labor.

If the increased specialization of labor and equipment derived from demographic and institutional changes have reduced the adaptive efficiency of the economy, it is possible that a technological Maginot Line has been created. In wartime, depending upon producing advanced systems with alternative resources may cost much in total resources and could yield strategic failure. Therefore, as new technologies are adopted in defense production, care should be taken not to follow too closely on the heels of technological discovery and to quickly and widely implement changes once introduced. However, there has been increased specialization of weapons production, largely in pursuit of operational performance and lower procurement cost, and new materials, skills, and equipment have not been quickly and widely adopted in the civil sector. In World War I, eighty percent of war goods came from standard civilian production lines; by 1941 the standard proportion had dropped to fifty percent; by 1963 it was only about ten percent. *Ceteris paribus*, this implies that more preparedness planning likely is needed. The alternative is to reverse the specialization trend.

The aircraft industry may be a particularly extreme example of this increase in specialization. It has been found that: "The U.S. aerospace industry has more of the more sophisticated directed numerical control systems...than any other industry we have seen or been advised of."[7] This means that aircraft production is near the technological frontier,

and probably has relatively few opportunities to use substitutes from other industries. In addition, because these types of machines are expensive they tend to be used more of the time than older, less capable machines. For example, one has observed numerically (computer) controlled lathes that continuously work titanium forgings for landing gear for 28 days. Several facts emerge from this: (1) titanium, a standard aerospace material, is difficult to work; (2) there is little slack in the use of these particular machines, at least during some periods; and (3) the cost in dollars and delay is significant if any of these parts are damaged in production.

There is no doubt that a shortage of specialized factors, such as machine tools and titanium forgings, is much more difficult to substitute around in a stress situation than are most production elements. However, with closer examination the technological Maginot Line increasingly is seen as a chimera. Even the most specialized machines are not always performing at engineering capacity and at their most difficult, unique activity. Therefore, potential exists to substitute in their use. Likewise, as seen in Chapter IV, neither raw titanium nor forging production is beyond substantial benefit from substitute sources within a year. This means that any preparedness planning done should be to identify where production line choices may follow research findings too closely. Potential substitutes should always be in mind for any system judged truly vital. In recent years, the

United States regularly has taken ten years to place new military systems in the hand of the troops.[8] While not by design, this allows time for development of potential substitutes. Let us now examine the potential inhering in technological change regarding future substitution opportunities.

Even if input-output coefficients and industrial data have been highly stable and yielded IPP and stockpiling calculations that were accurate in the past, this may be changing now. Observers, such as Toffler, find accelerating change in many elements of American life, change dramatic and pervasive enough to potentially upset present norms.[9] Particularly in defense industries, advances in metallurgy, computer aided design, testing, and manufacturing, and in group technology are seen by some as generating a veritable industrial revolution. IPP and stockpiling analysis must be sensitive to these changes.

The most modern weapons often are produced with very old machinery since the characteristics of the capital goods do not transfer to the product. However, numerically controlled machine (NCM) tools now are sometimes specially developed for military production so that greater accuracy or unusual geometric configurations can be attained. This is particularly true in aircraft production. The prevalent view is that the spin-offs of this military research and development have played a major role in making United States commercial aircraft technologically superior in recent years. This intimates that military aircraft production is significantly

more advanced than commercial aircraft production and employs inputs not generally in industrial use. This is pessimistic relative to this study's hypothesis. However, this intimation is invalid. Kamien and Schwartz have demonstrated that the aircraft industry has become more technologically progressive as the customer base has broadened and the Federal government has become less protective of industry firms.[10] Therefore, as time passes there is less probability of a technological Maginot Line from defense production leading commercial production techniques. This also means that if defense practices discourage adoption of commercial techniques, they may degrade wartime preparedness, both by achieving less performance and longer production thruput times.

Aircraft production is in the forefront in using NCMs. For example, at the end of 1973 (approximately the period addressed in this study) aircraft production employed some 2,850 NCMs out of a total of 28,600 in use in metal working industries. This was with NCM production of only 4,054 in 1974, some 1.2 percent of total domestic machine tool production.[11] Even so, these figures show that one year's production of NCMs could more than double the number in the aircraft industry. And much aircraft industry use is in building commercial aircraft. These numbers do not portray defense as using machines so specialized that substitutes would not be made available for them. Perhaps more importantly, there is a strong trend toward the use of NCMs in general

industry. This is quite optimistic for the future.

NCMs have wide-ranging potential for shortening production thruput times. They also can help ease the stress found is some sectors in Chapter IV. An important NCM advantage is that once a computer tape has been created for machining a part, additional tapes can be quickly cut. The same is true for computer aided testing and design. In addition, setup times for NCM jobs are much shorter. A machine shop survey has shown that production time, including setup on NCMs, averaged 25 percent of that on conventional machines. Even when the total production time was reduced 21 percent.[12] Case studies comparing conventional production methods with numerical control methods have found average manhour reductions that range from 52.2 to 76.1 percent over a wide variety of parts and machine operations.[13] These production thruput implications for the future, when many more NCMs are in use, make Chapters III and IV results appear even more robust in the future.

There are other aspects of NCMs that further indicate decreased need for stockpiling and IPP. First, these machines do not require more skilled machinists, tool and die makers, etc., because once the skill is on a computer tape, production can be monitored by much less experienced workers. Second, it is now possible to cut at much higher operating speed. Ultra-high-speed machining promises to large increase in cutting efficiencies, breaking barriers existing for at least fifty years. This reduces the need for coolants, ex-

tends tool life (in one example 100-fold), produces deeper cuts per pass, and greatly speeds cutting time.[14] Third, the reliability of NCMs is greater than that of skilled labor. The computer tape positions the cutting tool and constantly compares its location with the programmed position. If the machine approaches a tolerance limit, cutting is automatically stopped.[15] High reliability in all details in a weapon and few bottlenecks from spoiled work stock are important for a short thruput time.

Other important changes related to NCMs that are now being installed in plants are interactive graphics, computer aided design (CAD), and computer aided testing (CAT). These techniques bypass the need for tool and die makers and CAD and CAT can interact directly with computer aided manufacturing to boost productivity dramatically. At Rockwell International, CAD has increased the productivity on some jobs twenty-eight fold.[16] Recall from Chapter IV that the tool and die subsector was found to be a particularly difficult case for which to find timely substitutes. Likewise, testing equipment and labor were potential problems. CAT can substantially ease these constraints.

In addition to the linking of design, testing, and manufacturing, there is a strong trend toward using robots and to institute completely integrated computer aided manufacturing. These produce substantial labor and energy savings and avoid environmental and worker hazards. Half of the firms in the aerospace industry now use some computer aided assembly.

This boosts production rate capability and improves in-plant flexibility. It also would greatly increase mobilization potential. Many firms also are now using automatic riveting machines.[17]

Another important technological change now underway as an alternative to labor intensive assembly, forging, and/or machining is precision casting. Adoption is proceeding rapidly, particularly in aircraft and automotive applications. It has great promise as a more rapid alternative production approach. In one case, a single aircraft casting replaced more than 400 parts and the 2,200 rivets conventionally used to fasten them. Such developments echo the controversy during World War II between advocates of casting and those of machining. Machining dominated then because casting could not produce the reliability and strength needed, particularly in thin parts. It appears that these problems are overcome; some aircraft parts now cast are only .1 inch thick.[18] Because casting is a much simpler method of parts forming than machining, much time can be saved with broader adoption of this technique. Thus, substitution possibilities proliferate further and the need for present preparedness planning will continue to decrease.

Many additional significant technological innovations in metallurgy, metal forming, and materials bonding are now being aggressively pursued, some in specific manufacturing technology programs within aircraft production.[19] These initiatives also generally promote substitution and more

rapid production; i.e., will also continue to make present, essentially fixed coefficient, IPP and stockpiling obsolete.

We have found many examples of embodied and disembodied technological change which almost uniformly dictate that the hypothesis of Chapter I will become more supportable in the future. With more component manufacturing done on NCMs or in integrated machining centers, it becomes more possible for non-defense capacity to switch quickly to defense production as was found ubiquitously possible in Chapter IV. A machine operator in a plant producing civilian goods does not need to learn the peculiarities of a specialized defense material. Instead, she merely loads the work stock and computer tape. This eliminates the need for IPP for labor, tooling, machine tools, etc. Ensuring that computer tapes are not destroyed when peacetime production ceases would be an inexpensive initiative to boost wartime surge potential; this would be analogous to the present standard industrial practice of retaining tools and dies.

Another element of disembodied technological change that can yield a major decrease in production thruput time is group technology. It is a way to speed the materials flow through a plant by grouping products according to productive process used and/or product geometry. The USSR, Japan, and Germany now use this technique more than the United States, although it is being explored more here as NMCs and integrated computer aided manufacturing are increasingly adopted.[20]

NCMs using group technology are particularly adaptable

to the batch production environment of aircraft production. They provide a potential for a neo-mass production type of operation. In range of functions they are much more like the general purpose machine tools that served the Germans well during the World War II than the more specialized machine tools used by the allies. With a neo-mass production approach, many successive identical items could be produced on a machine. This avoids template, tool, etc., changes and can use a narrower range of labor skill. Larger production runs also save much of the loading, positioning, and perhaps measuring, time needed in batch production. This is particularly important for assessing the need for IPP because peacetime defense production runs are rarely long enough to become mature (therefore, the use of learning curves rather than marginal cost curves).

With increased production line maturity lead times for all inputs be more correctly gaged and greater benefits derived from group technology. This lack of maturity is particularly prevalent in fighter aircraft production and the practice of making design modifications after aircraft are in production exacerbates it. In fact, it is the low numbers to be produced and continuing product change that militates batch rather than mass production techniques. Batch production and numerous product changes are unlikely to be either money or time efficient in wartime when larger numbers and speed are important.

Sizeable gains in productivity are already being

achieved through use of sophisticated machine tools and integrated computer-aided manufacturing in batch process operations. However, their use is not uniform across the aircraft industry. Peacetime military procurement management could encourage the more rapid diffusion of the new technology.

Work standards are a related major initiative which is being adopted slowly in defense industry. They could yield substantial time savings in wartime by identifying present bottlenecks and time-wasting points. In peacetime, work standards and manufacturing technology initiatives are resisted because they are seen as threat to jobs and/or management prerogatives; i.e., adaptive efficiency is reduced by behavioral factors. In this situation the wartime motivation of labor becomes crucial; e.g., could minimum work standard be instituted quickly or surpassed in wartime? The potential exists, administrative capacity to harness it is needed.

More adaptive efficiency likely has been generated in defense production than in other industries, such as automobiles, by the combination of more frequent technological change and relatively small production runs. This is a result of a trend toward fewer, larger firms; those firms unable to innovate fast enough failed.[21] This trend has positive implications for the introduction of computer aided manufacturing and other new techniques because large firms more likely can sustain the risk and expense of these relatively expensive tools. Likewise, large firms may be

more amenable to adopting mass production techniques. This trend also reduces problems of company proprietary information, military specification compliance, and of the multiplicity of industrial standards.

The broad question of industrial standards and military specifications is a major concern. Both can make it more difficult to switch civilian production to defense tasks. Military goods output was greatly increased in World War II by converting to mass production and introducing new procedures. Today, systems involve many more production steps and are more specialized, seemingly making it more difficult to make such changes. However, standards and specifications can be expected to be relaxed in wartime. Likewise, occupational safety and health, environmental protection, and other regulatory constraints can be expected to be quickly relaxed in a wartime stress period. This would substantially aid a rapid buildup.

Another important insight is that modern production tasks can be subdivided, just like production was during World War II, and that today education levels and administrative capabilities are greater than then. Thus, as demand has increased so has supply. Additionally, today NMCs are neo-mass production aids that can promote this subdivision of labor and rapid conversion to defense production.

This chapter has found that the World War II mobilization still has relevance in assessing the ability of the nation to mobilize in a stress situation. While considerable

technological and institutional change has occurred since then, the same process of structural adaptation is both possible and needed. There are significant, but countervailing, differences between these economic baselines. Today, fewer resources are unemployed, or employed in agriculture, but at the same time there is much more per capita disposable income and a much larger service sector to shift to defense. In addition, today the larger absolute size of the manufacturing sector and the higher capital/labor ratio afford more opportunities to generate a World War II size reaction. Increased military goods production potential also inheres in today's economy because technological progress that has been adopted since World War II means that fewer inputs are needed per unit of output (assuming constant relative prices) than were required then.[22] Thus, weapons with World War II capabilities could not be produced with less of some, or possibly all, general factors of production.

The chapter has also revealed that there are many technological opportunities now present that promise to make defense production easier and more rapid in the future. Not only will the same defense goods cost less, but there will be more opportunities for substitution as the technological menu and the division of labor grow. The potential in the advent of NCMs, computer aided design, computer aided testing, ultra high speed machining, and precision casting, among other technologies, is so great that earlier chapters are likely to seriously understate the opportunities for substitution in

the future.

As a result of past and prospective technological and institutional change, therefore, there is less need for IPP and stockpiling as it has been practiced since World War II. If technological specialization is pursued in defense production without regard to production thruput time and the time needed to effect substitutes there is a constant danger of creating a technological Maginot Line. The present existence of such a barrier, however, that could necessitate large stockpiles and IPP efforts have not been found for the situation examined. However, sensitivity to substitution possibilities in an era of technological change is a legitimate main focus of a possible new type of preparedness planning that could be highly beneficial in improving the nation's adaptive efficiency in stress periods.

VII. FINDINGS AND IMPLICATIONS

The hypothesis that present IPP and stockpiling programs are unnecessary because sufficient opportunities now exist for timely substitution has been supported, except for a few sectors which provide a large proportion of output to defense. The search for this answer has included examination of the economic underpinnings of present efforts and focused upon a sector identified, using conventional tools, as likely to be particularly stressed in wartime. The stress postulated was larger than that usually used in preparedness planning. Because the analysis found potential substitution opportunities that could prevent strategic failure in this relatively difficult situation, the case for phasing out much of present IPP and stockpiling programs appears robust.

In establishing this overall conclusion, a variety of subsidiary findings were uncovered. The main argument is advanced that defense goods could usefully be conceptualized as containing a time dimension. This is because in a wartime stress period, the contingency for which they are developed, the quickness of their availability would be of central importance. The elasticity of supply, expressed in terms of thruput time, was proffered as an appropriate construct in assessing the ability to overcome a wartime shortage. Increasing wartime time elasticity is the essential purpose of all spending on IPP and stockpiling. However, present preparedness planning programs are not consistently focused

on this. Some of this difficulty appears to stem from the lack of attention given to time considerations in the economic analysis that underlies these efforts. In the main, economists have addressed Bayesian gradual adjustment situations to the exclusion of dichotomous, rapidly changing circumstances. Comparative static analysis is inadequate for preparedness planning purposes. It ignores the adjustment process which must be understood to confidently, and inexpensively, avert strategic failure of the economy under a war stress. This approach ignores both the time needed to effect chains of substitution and the fact that important learning takes place during the production process.

After this baseline has been established, the analysis employed an input-output model to make a succession of approximations aimed at identifying parts of the economy that would have to adjust most, and therefore were more likely to require preparedness planning. The main approach of considering only direct impacts of an hypothesized stress was found less useful than an approach that included indirect efforts, although both surfaced many defense goods producing sectors as experiencing large demand increases. The criterion of choice in identifying these sectors was also found to affect the sectors identified. The largest absolute change list included relatively large sectors and reflected their increased activity in wartime. The percentage change list, however, was much less likely to include general services sectors and more likely to include munitions and weapons

producers. Both approaches identified the Electronic Components, Communications Equipment, Aircraft, and Aircraft Equipment sectors, clearly these are all high stress loci. Additionally, when the proportion of total output taken directly by Defense and by other defense goods producers as an intermediate product was used essentially the same sectors surfaced.

Aircraft was high on all three lists and used much output from these other potentially high-stress sectors. It also was the sector which experienced the most pronounced increase in overall final demand. For these reasons, plus the fact that aircraft are likely to be militarily important weapons in a large conventional war, the aircraft industry was selected for more detailed subsectional analysis in a search for timely substitution opportunities.

This sector was found to sell to a moderate number of other sectors. Most output went to Defense, Exports, and to Airlines. Consequently, the opportunities for substitution on the demand side do not appear particularly large. Aircraft was also found to be a sector which received inputs from an exceptionally large number of sectors - thus indicating many avenues for substitution in supply. Examination of some of these input sectors' sales revealed that they sold to a wide variety of buyers. In the case of Machine Tools, Metal Cutting (the sector with the largest percentage increase in input to aircraft) about one quarter of all sectors took its output, even though its total output was rather

small. Aircraft directly received such a small amount of this sector's output that it was not revealed as a buyer when a one tenth of one percent cutoff was used. Of course, considerable indirect input from machine tool operations would nevertheless have occurred. The most important finding from the examination of inputs to Aircraft is that this sector took only a small fraction of the output of each sector making inputs to aircraft production. The sole exception, Aircraft Equipment, took a smaller proportion of output in wartime 1975 than in pre-war 1974.

The sector with the second largest proportion of output (9%) going directly to Aircraft was Aircraft Engines. In addition, this high technology sector sold slightly more than half of 1975 output directly to Defense. This is because the Department of Defense buys aircraft engines and provides them to military aircraft manufacturers. Thus, Aircraft Engines is an apparent serious constraint on a rapid increase in aircraft production. Further probing of the inputs to Aircraft Engines revealed that this sector also received a wide variety of inputs. However, once again, the fraction of these inputs bought by Aircraft Engines was low, even in wartime 1975.

The fact that sectors revealed as potentional bottlenecks were found, with few exceptions, to take only a small fraction of the output of input sectors was important evidence in support of the main argument. The study next examined both aggregate capacity and more specific capacities

to further assure that opportunities for timely filling of shortages would be available without IPP and/or stockpiling.

Inventories of both goods-in-process and final products can satisfy surges in demand particularly quickly. Even though businesses have made progress in inventory control in the modern era, it was found here that for durables there was no apparent trend in inventories relative to sales in the pre-1975 period. Also, there were sizeable real per capita inventory increases in aircraft and aircraft input sectors through the 1960s. In fact, the inventory to sales ratio in aircraft was increasing through at least the 1972 Census of Manufacturers.

Further examination of a wide variety of inputs used in aircraft production, including facilities, labor, engines, materials, stock items, machine tools, test instruments, metal working equipment, and tools and dies revealed only a few problems. Skilled labor availability was one of these. Defense production is skilled labor intensive, and this is particularly so in building aircraft engines. Even in this case, however, the potential was found to provide the needed labor within the first war year. A willingness to buy from non-customary suppliers, and to imaginatively use the capability that has been demonstrated in ETA training programs was found sufficient to fill the requirement. The underlying economic imperative is to aggressively pursue the division of labor. The present scopes of labor skills can be narrowed so that less training is needed to make a worker competent. The

same willingness to upset customary contractual practices is also essential in avoiding serious shortages in equipment, materials, and stock items. This means that commercial contract arrangements likely would have to be overturned to make capacity available quickly for military production during the first year after a war began.

A pre-war national policy that vital weapons systems would be supported on a priority basis is a key step in assuring timely inputs to virtually all elements of aircraft manufacture. Most metals, metal ores, and forgings are primarily used in civil pursuits and have much capacity to divert to defense needs. Titanium metal was found as an exception. Even here, substitute sources could be available if multiple shifts and alternate ores are used and paint production restricted. It should be understood from the outset that the war would preempt scarce resources and that they would not be available for civilian consumption. Most likely this would be done by direct government controls, although taxing away real per capita disposable income could also do the job if it did not impair work incentives. The INFORUM results in this study show that the tax approach could be a substantial benefit in dampening civilian demand.

Another significant finding which supports the study hypothesis is that present industrial capacity contains a great deal of slack. Machine tools are idle much of the time, as is the stock they work. This slack exists because of incomplete data collection, inconsistent and inaccurate

capacity measures, and habitual and customary practices.

The idea was introduced that substantial X-inefficieny exists that might make more production available in wartime than believed possible in the pre-war period. The X-inefficiency idea has not been linked to a wartime transition situation before, but it appears to be an important consideration in this argument. The record of World War II was found to be consistent with the idea that wartime behavorial changes yielded substantially more output than previous estimates of capacity dictated. Of course, the term X-efficiency was not used then, it had not been coined. It certainly appears appropriate, and at least as good a description as "miracle" - which is the term used frequently in the post-war period. The linking of X-efficiency to the preparedness planning circumstance in this study showed that expected X-efficiency gains could be enough to provide production gains at least as large as the defense increment assumed. In a broader perspective, this study concludes that it is highly conservative, and expensive, to not include behavorial elements in preparedness planning.

Consistent with an expectation of wartime behavorial change, the study finds that input-output models, and the peacetime data bases that drive them, should not be expected to very usefully forecast wartime sectorial demands. Wartime stresses are likely to drive the mix and level of economic activity far from peacetime norms, thus exacerbating problems with conventions used in input-output. In particular, there

are problems in sectorial aggregation and period of coverage.

The study has found that there presently appears to be substantially more potential for wartime production than is commonly accepted by preparedness planners. Nevertheless, it is possible that present trends, particularly in technology, might invalidate these findings in the future. Because the nation is likely to continue to value the ability to react to a large conventional war stress without strategic failure of the economy, the study probed past and incipient technological change to evaluate this possibility. Certainly, resources would not be diverted today in the same way to react to a war stress as they were in World War II. In the 1970s the service sector, not agriculture, provided the larger pool of divertable labor. Likewise, today it was seen that the larger amount of real capital per capita available provides much more of a buffer. However, it was also found that labor potential today is more completely employed than it was at the beginning of World War II. This implies that more care would be necessary now in allocating labor. Furthermore, if the trend continues, even more attention will be required in the future.

Technological advances in metal working are also consistent with this relative labor shortage, and with an increasing capital/labor ratio. The trend toward NMC tools, group technology, computer aided design and testing, robots, and new metal forming and bonding techniques means that more will be done with less in the future. The examples cited demon-

strate that substitution opportunities and thruput times in the future are likely to allow easier reaction to a wartime stress than they have in the past. The conclusion of this study seems likely to be even more valid in the future.

While present stockpiling and IPP programs are not warranted, at least on the scale now pursued, there is a need for some form of monitoring of production capabilities. The analysis indicates that through searching out substitution opportunities and being sensitive to the time needed to effect substitutions many apparent shortages can be overcome. Much of this effort need not be in a separate, formal IPP or stockpiling program; it can be incorporated in ongoing economic data collection and in defense systems' acquisition. Let us now examine the characteristics of such a new approach derived from the analysis above.

The core should be a national objective function which includes the production timeliness for weapons vital in preventing strategic failure. This is much more likely to keep peacetime costs lower than the present static, fixed coefficients approach. The present lack of attention to timely substitution ignores possibly the largest advantage over the Soviet Union in a conventional war that the United States has, the size and resiliency of the economy.

The idea of time-costing should also become more recognized in non-crisis economic decision making. As the division of labor increases and production and markets become more complex, the time needed for information flow grows as

does the potential gain from learning curves. Time-efficiency can yield a pattern of substitution and intersectorial final demand different from price induced changes. This is signaled by the fact that price elasticities vary with the time horizon used. It was demonstrated in Chapters III and IV when some subsectors and factors were found to have easy substitution possibilities while others require much more effort.

Attention to production thruput time is particularly critical during the initial part of a mobilization. When there is a danger of strategic failure it should supplant performance improvement and dollar cost considerations as the key decision variable. An important ancillary implication is that production thruput time should become an additional prime management criterion in peacetime weapons procurement. This change would put substantial pressure upon weapons designers and production planners to build different types of weapons than are generally produced now.

The inquiry has made it clear that the analysis underlying planning should be much broader in scope than it has been before resources are bought or retained solely for preparedness. Only five to six percent of GNP has been spent on national defense in recent years, and about one third of this is for procurement. However, planning has paid almost exclusive attention to current defense producers. This tacitly assumes that the other ninety-eight percent of the economy could not contribute responsively. Such a narrow approach is

justifiable only because vital defense goods are not identified and neither which civilian producers could be shifted to war goods nor the way to do so has been studied.

There are more opportunities for such shifts now than at the beginning of World War II with the larger peacetime defense base and more comparable activities in the private sector. In 1943 about 44 percent of GNP (Chart 3A) went to defense and the population was sustained. Today, the average real per capita disposable income is twice as large (Table 3A) and per capita stocks of goods, particularly consumer durables, are much larger. In addition, in industries such as electronics, some civilian products are more advanced in performance than items in peacetime standing forces.

Governmental ability to quickly reorient resources in wartime, even after understanding what to change, is difficult to gage. In World War II, with Hitler's extraordinarily clear strategic warning, administrative capacity this strong did not exist. The view was:

> "...the public was in no mood to see the production of civilian goods curtailed and, in general, seemed to believe that the country could prepare for war and conduct all its regular peacetime pursuits at the same time."[1]

This attitude may be worse today. For example, Cooper senses "...a developing brittleness in the publics of modern democracies, an unwillingness to accept setbacks in levels of income..."[2] Consequently, it is essential to have vital systems and their inputs identified so that public support can be gained quickly.

Development of input-output matrices which incorporate government forced substitutions for production of vital systems should be pursued. Output from using these then could guide the minimizing of societal welfare losses. In developing these matrices industries should be conceptualized as a bundle of functions performed. The present combination of broad product and some process related sectors is only a first approximation of functional analysis. A functional approach would make it easier to assess the opportunities for, and speed of, substitution to fulfill vital needs; it also would eliminate the increasing secondary products problem. At present, functions needed in defense production are fulfilled by elements of many sectors. Meanwhile, other sectors may be capable of quickly entering the field and performing the function.

Related to the need for a broader search for suppliers for defense is the necessity of avoiding rigidity in pursuing technological opportunities, a so called Maginot Line. With accelerating technological change, more new technology has been incorporated in each weapon's model. This tends to specialize the industrial base and yields a longer development period. Low production numbers, long and complicated development, and lack of producibility planning have combined to increase production thruput time. This study implies that larger numbers of each weapon should be purchased (yielding fewer models with the same budget) and much attention paid to thruput potential. With larger procurements, increasing re-

turns will sometimes be captured. This is in addition to the larger benefits from learning-by-doing.

A specific action which could help to prevent a technological Maginot Line is peacetime exercise of planned wartime production rates for either whole products or components. Another, is to systematically reduce weapons specialization, particularly through simplification and standardization of design criteria. Sometimes design complexity and performance sophistication have been confused. This is exacerbated by a tendency in United States industry to over-machine non-critical parts. Such improvements could reduce peacetime costs and increase preparedness. Similar circumstances were important in World War II Germany's dramatic shift to increase production. A third useful action is to more rapidly diffuse technological advances throughout industry.

The adoption of less specialized production techniques would be encouraged by no longer providing free loans of government equipment to private defense producers. Now, modern weapons sometimes are produced with very old technology owned by the government. In addition, the use of multi-year contracting for major weapons systems might encourage small firms to invest in new quasi-mass production methods. However, multi-year contracting would have to emphasize truly open competition lest the number of firms (and therefore likely capacity) quickly available for defense production be reduced. An intriguing intermediate step may be to multi-year budget but continue to contract annually. Both a multi-

year approach and no free equipment loans would be major changes in defense policy.

Another major change which could improve the adaptive efficiency of the industrial base is to allow the DOD to interact directly with subcontractors and suppliers. The aircraft engine industry is something of a precedent for this. These generally smaller concerns increasingly have been at the mercy of prime defense contractors as prime contractors have decreased in numbers and increased in size. As a result, subcontractors and suppliers are often forced to absorb the shocks created by DOD monopsony buying. As specialization has increased, and the cyclical nature of defense procurement has persisted, these small firms have failed, switched to civilian products, or have been vertically integrated with prime contractors. This interaction could take the form of providing direct subsidies to prompt conversion to production techniques which use less critical materials, equipment, tooling, etc.[3] This leverage could also be used to insure that accurate inventory data are provided on a continuing basis to government data collectors.

This study provides a more effective approach to preparedness planning by adhering more closely to the insights provided by economics. However, economic inquiry and data collection for preparedness planning purposes should be substantially reoriented to facilitate tracing the functional use of factors and the ease, and speed, of using substitute factors for defense and vital non-defense needs.

Preparedness planning conceptually satisfies an option demand; a major conventional war is an uncertain, low probability, event with a large negative payoff. The limited resources available for this planning should be allocated only to assure timely provision of vital items that might cause wartime collapse. If series of tactical shortages of these are prevented, there is virtually no chance that collapse will occur because chains of substitutions will be put in motion in reaction to the stresses experienced. The size and diversity of the United States economy provides substantial protection. The analysis above has shown that at virtually all levels of production (affecting demand and supply of materials, labor, equipment, and intermediate goods) there are myriad opportunities to substitute around impending shortages. As the division of labor has secularly increased the opportunities for substitution have concomitantly proliferated. Behavioral factors and incipient technological changes also dictate that this will continue to be the case. Any planning done by the Federal Government should be sensitive to these behavioral factors and the time needed for substitution. Such an approach can improve preparedness, and at less cost.

APPENDIX A. HISTORICAL PRECEDENT

This appendix is directed at the question of whether the historical record of World War II and the Korean War shows that a munitions production response might be larger and quicker than prewar data would indicate. This is directly in support of the hypothesis of Chapter I; if past wars evidenced much more production response than expected with then existing preparedness plans perhaps the economy today could also do better than standard analyses show. Possibly present stockpiling and IPP programs could be terminated, or alternatively, more protection could be expected for present spending.

Most of the historical references in this study are included here, although some appear throughout the paper. This limited historical reference augments the main text and provides perspective on the type of stress situation under study. In addition, there is the concern than the dead hand of past experience, particularly World War II, has inhibited development of new national planning tools. Possibly the United States has not learned from the World War II experience, much as Grether feared: "We could very easily find ourselves in the same situation as during 1941 when we proceeded piecemeal rather than on the basis of a comprehensive and coordinated plan."[1]

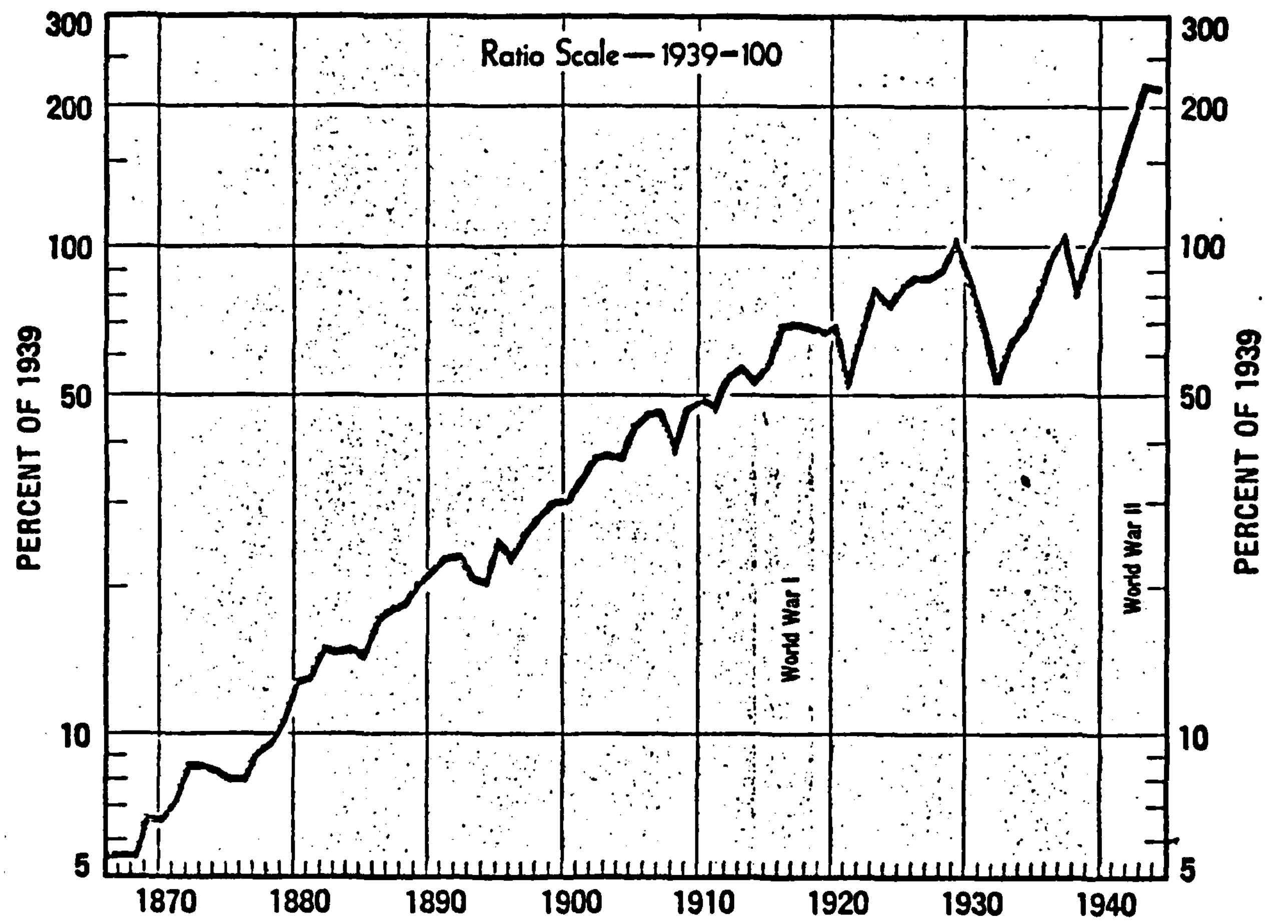
Most of the data presented are for World War II because that is largest mobilization in modern United States history.

Some of the tables display illustrative pre-World War II years, the Korean War period, a pre-Vietnam 1964, 1974, and 1975 as a baseline for the input-output analysis of 1974 and 1975 in the main text. All tables and charts in the appendix are labeled with an "A" suffix for ease in locating them when referenced.

Chart 1A sets a very broad historical context for this quest for historical evidence. This plot of United States industrial production from the end of the Civil War through World War II tends to dim the reputed miracle of World War II. Observe that a trend line for the entire period would pass very close to the peak levels attained in World War II. This argues that the nation merely achieved a production level that its historical trend line would indicate. The chart also shows that the sustained rate of increase from 1938 to late 1944 was a record, nearly matched only by the intial rebound from depression lows between 1932 and 1937.

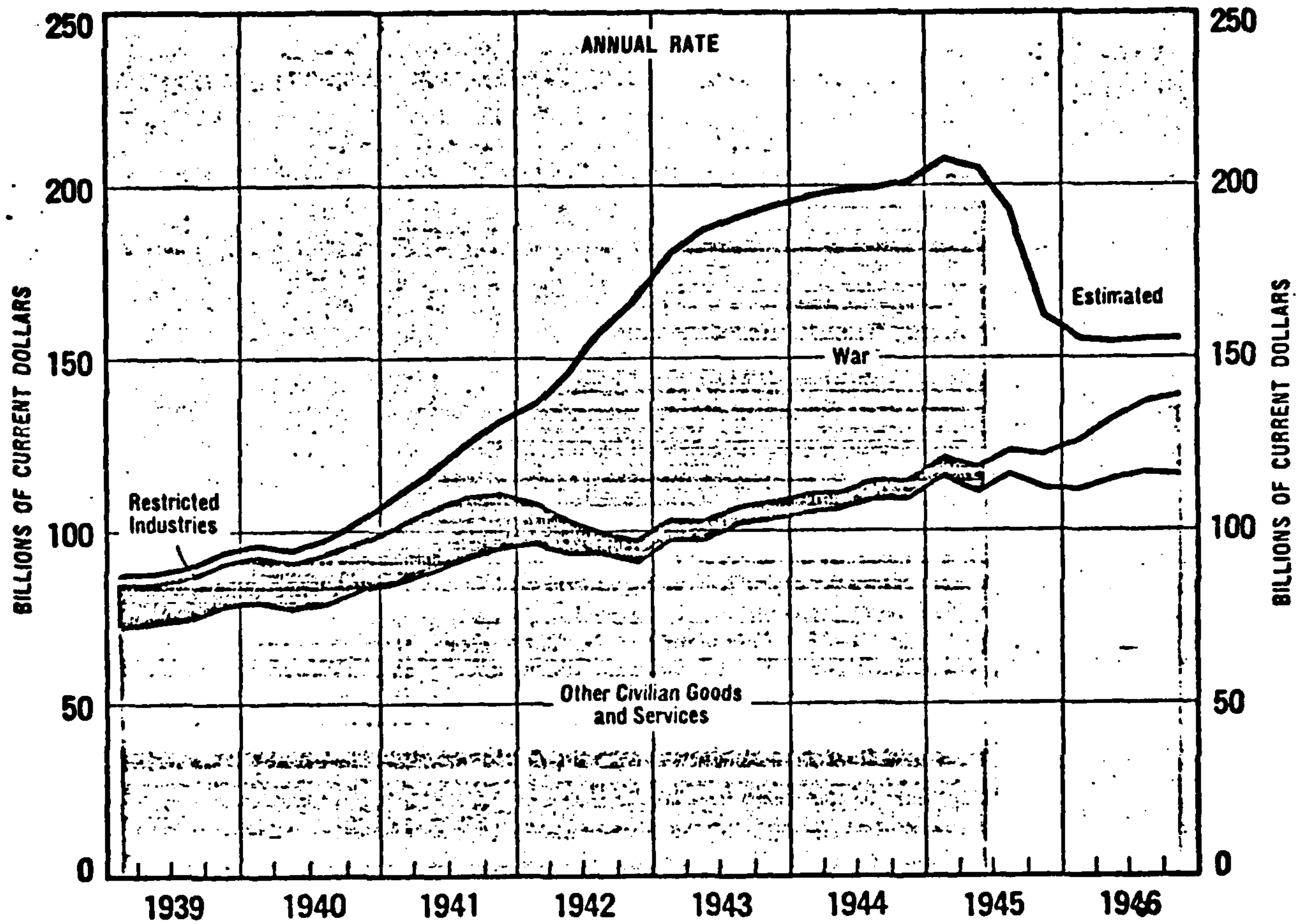
The record during this wartime period is made clearer with the use of Chart 2A, a plot of the GNP trend. One often overlooked important fact is that civilian goods and services production was essentially maintained during the war. Most Americans were able to buy more during the war than they could during the 1930s. However, output of restricted industries was reduced to about one-fourth of 1941 levels during the war, generating much publicity about shortages. The lack of sacrifice on the part of Americans relative to that of the British was substantial. Between 1938 and 1944

CHART 1A: U.S. INDUSTRIAL PRODUCTION SINCE THE CIVIL WAR



SOURCE: U.S. War Production Board, Official Munitions Production of the United States, Washington: Government Printing Office, 1947.

CHART 2A: GROSS NATIONAL PRODUCT



Note—Restricted Industries include motor vehicles, consumer durable goods, nonwar construction, and consumer purchases of gasoline.

SOURCE: U.S. War Production Board, Official Munitions Production of the United States, Washington: Government Printing Office, 1947.

consumer goods and services purchased in the United Kingdom fell by 22 percent.[2] Thus, it appears that the United States may have had substantially more ability to produce munitions during World War II if they had been needed.

Chart 3A documents the dramatic gain in munitions production that was achieved. Both the total amount of production and the speed with which it increased, particularly in the year after Pearl Harbor, are key precedents for future mobilizations. Observe that during 1942 real munitions output rose from about $1 billion to some $3 3/4 billion. This was done by massively involving civilian goods producers in munitions production. Such a percentage response is what some believe the nation would need today in the event of a full scale conventional war with the Soviet Union. Today, however, the economy would not be in the recovery phase from a depression with the munitions base already rapidly expanding in support of an active war between other combatants. On the other hand, today a larger standing force is maintained along with at least some preparedness planning. At the same time there has been a narrowing of the proportion of the economy involved in defense goods production. It is possible that this makes IPP and stockpiling more essential than before.

Let us now examine the production indices for the World War II period in more detail. Table 1A shows the important durable goods sector and some key subsidiary aggregates. Durable goods production had recovered more rapidly than

TABLE 1A: SELECTED INDUSTRIAL PRODUCTION INDICES
(1935 - 1939 Average = 100)

YEAR	TOTAL DURABLES	IRON AND STEEL	MACHINERY	TRANSPORTATION EQUIPMENT	NONFERROUS METALS
1939	109	114	104	103	113
1940	139	147	136	145	139
1941	201	186	221	245	191
1942	279	199	340	464	214
1943	360	208	443	735	267
1944	353	206	439	719	259
1945	274	183	343	487	204

SOURCE: U.S. Bureau of the Census, Statistical Abstract of the United States 1950, 81st Congress, 2d Session, House Document 382 Table 911, p. 755.

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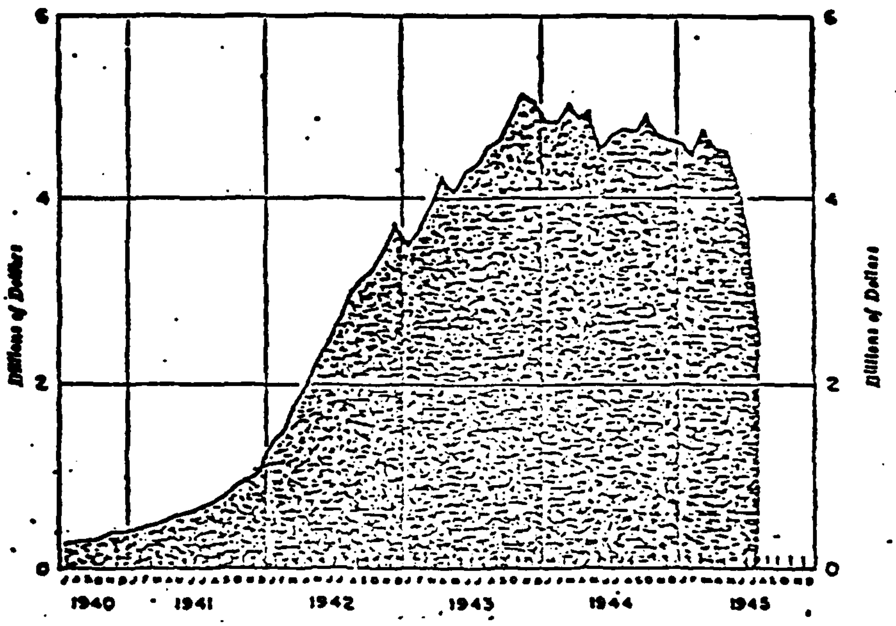
TABLE 2A: MANUFACTURING PRODUCTION AND CAPACITY INDICES FOR SELECTED YEARS[1]

YEAR	MANUFACTURING PRODUCTION	YEARLY% CHANGE	YEARLY% CHANGE	MANUFACTURING CAPACITY[2]
1940	126	17	16	NA
1941	168	42	33	NA
1942	212	46	27	NA
1943	258	46	22	NA
1944	252	-6	-2	NA
1945	214	-38	-15	NA
1951	236	18	8	56.7
1952	245	9	4	59.2
1953	267	22	9	61.8
1954	249	22	9	64.1
1964	392	14[3]	6[3]	94.5
1974	626	23[3]	6[3]	153.7
1975	563	-63	-10	158.1

Notes:
1. 1935-1939 Average = 100. For 1929 the total manufacturing index was 110.
2. Data not available for years to 1948 but for 1942-1944 could reasonably be assumed close to actual production. Later years index based on 1967 output.
3. Yearly average since last date displayed.

SOURCES: Board of Governors of the Federal Reserve System, Federal Reserve Measures of Capacity and Utilization, February, 1978, p. 30. Post 1945 data renormalized to 1935-1939 base.

Chart 3A. U.S. Munitions Production, July 1940--August 1945
(August 1945 munitions dollars)



Source: U.S. Bureau of Demobilization, Industrial Mobilization for War, Vol. I, Program and Administration, p. 961.

total manufacturing from the depression lows. However, in 1940 it was still somewhat below 1929 levels. The relatively rapid durables increase in the late 1930s was aided by production for European combatants. Note that there was about a twenty-eight percent increase in durables between 1939 and 1940, before the United States entered the war. From 1940 to 1941 there was approximately an additional forty-five percent increase. Care should be exercised in extrapolating these yearly increases to the 1970s because industrial expectations then were that a large and increasing defense market was prospective. As a result, many long lead time adjustments were begun in anticipation of sales.[3]

Table 1A also reflects that production increased across

a wide range of sectors until demand slackened in 1944. The performance of the Transportation Equipment sector is of particular interest because this is the sector that produced the tracks jeeps, ships, tanks and aircraft so central to military operations. Note the more than seven-fold increase between 1939 and 1943 (including 69 percent between 1940 and 1941). This is a sectorial aggregate which is likely to have to increase dramatically in a modern war. The main case study of this study focuses upon the aircraft industry, a subsector within this aggregate. The other sectors increased by amounts much more typical of overall manufacturing, as can be seen on Table 2A. This table also shows yearly changes and present changes during the war.

By way of comparison, the production figures for the Korean War period show much smaller absolute and percentage increases, although from a larger base. This period also shows a steady increase in total manufacturing capacity, about four and one-half percent per year. The utilization data in the same source also show that in the years 1950-1954 manufacturing utilization peaked at 89.2% in 1953. This demonstrates that the Korean War was less than a full potential effort. In 1953, some three years after the war began, total manufacturing was only about four percent greater than it had been in 1943, about three years after World War II began. Moreover, during the Korean War civilian products were not curtailed as in World War II. Overall, the Korean War data are not indicative of serious industrial stress.

The last three years displayed on Table 2A provide a bridge between the World War II record and the period addressed in the INFORUM analysis in the main text. This comparison documents the fact that a modern war would begin from a much larger production base and manufacturing capacity than have previous wars. It is interesting to note that the yearly drop between 1974 and 1975 in the "energy crisis" recession was larger in absolute amount than any of the yearly increases during World War II. Because Americans clearly survived 1975 without significant privation, it is evident that substantial manufacturing production potential exists for transfer during a defense emergency. The relative per capita disposable income figures between World War II and the mid-1970s further document this fact (Table 3A). This is with a substantially larger tax burden already subtracted in the later years. The central question remaining is whether the key structural adjustments can be made quickly enough - the main text addresses this.

Now let us return to the baseline of the World War II production increase with primary attention to labor factors. One is particularly interested in evidence of labor hoarding or underemployment because this phenonmenon is considered to be present in modern business cycles and would affect the mobilization capability. If labor productivity in manufacturing decreased during the 1930s (compared with the 1920s) it might be evidence that hoarding occurred. If it occurred and persisted for those many years this excess labor

capacity then could have propelled the great spurt in production in World War II. Table 4A contains data on labor productivity during these years.

TABLE 3A: REAL PER CAPITA DISPOSABLE INCOME

($72)

YEAR	DISPOSABLE INCOME[1]
1939	1616
1940	1704
1941	1967
1942	2214
1943	2349
1944	2502
1945	2486
1950	2347
1951	2337
1952	2366
1953	2449
1954	2443
1964	3073
1974[2]	3937
1975[2]	3978

NOTES: 1. Consumer price index used as deflator.
2. Values shown are about 1% lower than values used in INFORUM. More recent data series used here than in illustrative INFORUM run.

SOURCES: Derived from U.S. Department of Commerce, Business Statistics, 1969, pp. 7, 40, and 67; Business Statistics, 1975, pp. 8, 41, and 68; Survey of Current Business, January, 1977, pp. S-2 and S-13.

The labor force participation rate did not change significantly when the unemployment rate jumped and the output per worker decreased during the first half of the 1930s. However, with the significant drop in the length of the work week (evidence of underemployment), output per manhour in manufacturing rose during most of the depression. Manhour productivity should have increased with little change

TABLE 4A: LABOR CHARACTERISTICS IN THE 1930s

YEAR	PARTICIPATION RATE (%)	WORKWEEK (HOURS)	OUTPUT/WORKER[1]	OUTPUT/MANHOUR[1,2]
1929	55.1	44.2	59.2	52.0
1930	55.0	42.1	55.0	52.3
1931	55.2	40.5	54.7	54.0
1932	55.4	38.3	50.3	50.5
1933	55.6	38.1	49.2	54.9
1934	55.7	34.6	50.2	57.4
1935	55.6	36.6	53.5	61.2
1936	55.7	39.2	58.3	61.6
1937	55.9	38.6	59.5	60.7
1938	56.0	35.6	58.9	59.9
1939	56.0	37.7	62.4	65.4
1940	56.0	38.1	65.2	68.2

Notes: 1. Index, 1958 = 100. Gross private domestic product divided by persons engaged in the private domestic economy.
2. In manufacturing.

Sources: U.S. Bureau of the Census, *Historical Statistics of the United Colonial Times to 1970, p. 126, 162.*
U.S. Bureau of the Census, *Historical Statistics of the United Colonial times to 1957*., p. 92.

in participation rate and a decreasing work week if diminishing returns existed. Thus, there is evidence that diminishing returns existed and that labor hoarding was not prevalent during most of the 1930s. However, 1939 and 1940 are notable exceptions - as the work week increased, productivity increased. This could have been because demand increased in anticipation of war in Europe and hiring and work hours lagged the demand increase. An important message of the 1929-1940 data is that the work week was shorter and labor productivity higher at the end than at the beginning, the opposite of modern business cycle findings. Thus, labor underemployment may be more of a modern phenomenon as screening and training costs have risen. During cyclical downturns (at least the shorter ones experienced since the 1930s) there may be more labor hoarding than in the pre World War II period. Consequently, this is one reason to expect more potential for rapid expansion now than then.

The surge in production during World War II, reflected in the 1938-1940 statistics may be explained in another way. Perhaps during the 1930s the smaller number of workers in plants had to perform a wider variety of tasks related to the production of their firm's output. Indeed, possibly during this period, product lines were broadened in the particularly difficult quest for sales. If workers gained a wider than usual mix of experience they would be capable of moving into a wider variety of jobs when demand picked up and perhaps be more motivated in the new jobs. This could be both because

they were more satisfied in their "new" station and because they were demonstrating their competence in positions to which they might not have realistically aspired, five or ten years earlier. In either case, there is a boost in efficiency with behavioral roots.

From management's point of view, this cadre of depression seasoned workers may have been particularly substitutable within the production process when the wartime surge in demand came. Consequently, the nation experienced an unexpected boost in production, but in this interpretation, of a more allocative efficiency nature. Labor force utilization during World War II, the Korean War, and for selected later years is shown on Table 5A. Particularly during World War II there are dramatic trends. The labor force participation rate increased and the unemployment rate decreased during World War II through 1944. By then, desired war production rates had been achieved and substantial consideration was being given to reconversion to civilian production.[4] The participation rate increased for both men and women with a larger increase for women. These increases in participation rates are evidence that the necessary complement of labor was available to activate previously dormant industrial plant and equipment capacity and to create new capacity. The dramatic decrease in the unemployment rate from 17.2 percent to 1939, to 1.2 percent in 1944 is evidence that labor markets were very tight. This is further confirmed by the leap in the length of the manufacturing workweek between

Table 5A. Labor Force Utilization in Selected Years

Year	Civilian Labor (mil)	Employment (mil)	Unemployment Rate (%)	Manufacturing Workweek (Hrs)	Participation Rates[1] (%) Total	Men	Women	Military (mil)
1939	55.2	45.7	17.2	37.7	56.0	—	—	0.33
1940	55.6	47.5	14.6	38.1	56.0	82.6	27.9	0.54
1941	55.9	50.4	9.9	40.6	56.7	83.5	28.5	1.62
1942	56.4	53.8	4.7	43.1	58.8	85.3	30.9	3.97
1943	55.5	54.5	1.9	45.0	62.3	87.3	35.7	9.02
1944	54.6	54.0	1.2	45.2	63.1	88.4	36.3	11.41
1945	53.9	52.8	1.9	43.5	61.9	86.7	35.8	11.43
1950[2]	62.2	58.9	5.3	40.5	59.9	86.8	33.9	1.46
1951[2]	62.0	60.0	3.2	40.6	60.4	87.3	34.7	3.25
1952[2]	62.1	60.3	2.9	40.7	60.4	87.2	34.8	3.64
1953[2]	63.0	61.2	2.9	40.5	60.2	86.9	34.5	3.56
1954[2]	63.6	60.1	5.5	39.6	60.0	86.4	34.6	3.30
1964[2]	73.1	69.3	5.2	40.7	59.6	81.9	38.7	2.69
1974[2]	91.0	85.9	5.6	40.0	61.8	78.1	45.1	2.16
1975[2]	92.6	84.8	8.5	39.4	60.9	77.3	43.7	2.13

Notes: 1. Includes the Armed Forces
2. Persons 16 years old and older, other years use 14 years old

Sources: Bureau of Labor Statistics, Employment and Earnings, March, 1978, pp. 31-32.
Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1970, Vol I, pp. 126-138, 131-132, 169-170, Vol II, p. 1141.
Bureau of the Census, Historical Statistics of the United States, 86th Congress, 1st Session, House Document 33, Series D1-12 and D13-25, pp. 70-71.
Bureau of the Census, Statistical Abstract of the United States, 1978, pp. 379, 398.

1940 and 1942. The increased participation and lower unemployment yielded an increase in civilian employment of 8.3 million between 1939 and 1944; this was in addition to the large increase in the armed forces.

The labor situation was somewhat different during the Korean War. The labor force participation rate at the war's inception was significantly higher than it had been in 1940. In fact, it was higher than the 1942 level. During this war the rate changed relatively little for both men and women. Once again, the unemployment rate was reduced but this time there was not a large pool of unemployeds, with only 5.3 percent out of work on average in 1950 (down from 5.8 in 1949).

The contrasts between the World War II era and the situation in the mid-1970s is dramatic with regard to labor. In 1974, the participation rate stood at 61.8 percent, only 1.3 percent below the 1944 peak. The 1974 total is based on those 16 years old and older, and the World War II data counted those 14 years old and older; this reduced the World War II rate somewhat. The significant point is that in 1974 the participation rate without a war approximated the rate at the height of the World War II. Therefore, there was not as much slack available to be drawn up. Female participation rates in 1974 were notably higher than in 1944. In addition, the total, as well as female rate, have reached new historic highs since 1974; the total rate was up to 62.8 percent in 1977.[5] Likewise, an unemployment rate of 5.6 percent in 1974 provided much less slack than existed at the beginning of

World War II and only about as much as during the Korean War.

The absolute amount of change as well as the percentage changes are noteworthy, particularly during the brief span of World War II. Between 1940 and 1941 the military forces increased a net of 1,080,000 and the civilian labor force still increased about 300,000. Concomitantly, civilian employment rose about 2,900,000, indicating the unemployed of 1940 finding jobs.

With these changes, one would expect high and increasing labor turnover rates. Indeed there was; Table 6A documents this. The historically high labor turnover rates should have substantially reduced allocative efficiency in the short run. Additionally, histories of the United States' war effort impress one of how confused government policy was, surely generating much economic inefficiency.[6] Nevertheless, the data show that these inefficiencies were overcome with net increases in productivity. From Tables 7A and 8A note that productivity in all categories rose during the war from prewar levels. The most dramatic increases occurred between 1940 and 1941. This is surprising at a time when people who had been unemployed for a substantial period, and others who never have been in the industrial labor force, including women, were sent into the factories. Production returned to previous aggregate levels, although with a signficantly changed mix. In addition, productivity almost uniformly continued to rise through the war, seemingly indicating the input of increasingly more qualified labor and better capital

equipment. Note (Table 7A) that the increases per unit of capital were even larger than per unit of labor. This led the increases in total output per total input (between 1940 and 1941 from 122.0 to 131.3, or 7.6 percent). These changes are ones that probably can not be captured in input-output coefficients or predicted from a non-crisis data base.

TABLE 6A: AVERAGE MONTHLY MANUFACTURING LABOR TURNOVER
(Per 100 employees)

Year	Accession Rate	Total Separation Rate
1939	5.0	3.7
1940	5.4	4.0
1941	6.5	4.7
1942	9.3	7.8
1943	9.1	8.6
1944	7.4	8.1
1945	7.7	9.6

SOURCE: Bureau of the Census, Historical Statistics of the United States, 93rd Congress, 1st Session, House Document 93-78 (Part I) Series D1022-1028, p 181.

These increases in overall productivity are not completely reflected in the data for manufacturing alone. On Table 8A note that while productivity per worker trended up until 1945 when war production was slowed, productivity per man-hour decreased. However, the decrease is suprisingly small, varying from less than one percent to about two percent per year. It did not keep pace with increases in the intensive margin of weekly per capita hours, indicating that the effect of diminishing returns was small. It really was even less than this suggests. Recall from Table 6A that there was substantial labor turnover, with many new people entering the workforce. This extensive margin gain also

TABLE 7A: INDEXES OF NATIONAL PRODUCTIVITY
(REAL GROSS DOMESTIC PRODUCT, 1929 = 100)

YEAR	ECONOMY/MANPOWER	UNIT LABOR	UNIT CAPITAL	TOTAL INPUT UNIT
1939	122.2	123.6	110.4	120.2
1940	124.0	124.4	114.9	122.0
1941	134.6	131.3	131.7	131.3
1942	136.6	131.3	140.2	133.1
1943	141.5	134.1	150.4	137.3
1944	152.6	144.5	161.4	147.9
1945	159.0	150.9	160.7	152.9

SOURCE: U.S. Bureau of the Census, Historical Statistics of the United States, 87th Congress, 1st Session, House Document 33, Series W1-11, p. 599.

TABLE 8A: LABOR PRODUCTIVITY IN MANUFACTURING

YEAR	EMPLOYMENT INDEX 1	AVERAGE WEEKLY HRS.	MANUFACTURING INDEX 2	PRODUCTIVITY WORKER	PRODUCTIVITY TREND/MANHOUR
1940	107.5	38.1	125	1.16	3.05
1941	132.8	40.6	162	1.22	3.00
1942	156.9	42.9	199	1.27	2.96
1943	183.3	44.9	239	1.30	2.90
1944	178.3	45.2	235	1.32	2.88
1945	157.0	43.4	203	1.29	2.98

SOURCE: Bureau of the Census, Statistical Abstract of the United States, 81st Congress, 2d Session, House Document 382, Table 215, p. 179, Table 911, p. 755, and Table 240, p. 203.

1. 1939 = 100
2. 1935-1939 average = 100

productivity should be the result of both. On balance, this is a surprising phenomenon that substantiates previous accounts that marvel at the general surge in production or at increases in individual industry or plant outputs.[7] It is possible that both popular and economists' perceptions of the war were substantially in error because the accounting for the inputs may not have been complete. Problems have been uncovered regarding the accounting for wartime production and the resulting capital stock.[8] However, with the attention paid to World War II it seems unlikely that inputs of labor and capital were substantially undercounted. The overall result seems to indicate more than gain in allocative efficiency. This subject is treated further in Chapter V.

The findings of this appendix are that the United States was able to substantially increase overall output and to dramatically boost munitions production. The size of the increase plus the structural shift achieved should not have been expected from prewar peacetime data. Moreover, there is not compelling evidence that the nation ever came close to its limit in munition production potential. The increases of inputs on both the extensive and the intensive margin should have yielded significant diminishing returns, particularly given the labor turbulence found, but they did not. The fact that civilian goods and services, other than for the relatively few restricted industries, increased during war also shows that more could have been done if needed.

The appendix also surfaces some cautions about the ability of the economy of the 1970s to generate an initial

rapid rate of increase similar to World War II. It is clear that there was a strong uptrend in industrial production for nearly three years prior to December 1940. There also was a significant uptrend in pre-war munitions production. Even more important, very unusual economic circumstances preceeded World War II. Production had been so depressed for so long that substantial slack existed that could be quickly drawn up. Indeed, the industrial production achieved during the war did no more than reach the long term trend. Thus, the rate of build up at the beginning of World War II should not be expected today unless possibly if more pre-war planning of expansion is done. On the other hand, the much larger economy of today has the aggregate manufacturing capacity to far exceed World War II amounts of increase. To do so quickly depends upon the ability to make the necessary structural shifts in an orderly and timely way.

APPENDIX B. THE INFORUM MODEL

The Interindustry Forecasting Model of the University of Maryland (INFORUM) is an approximately two hundred sector open input-output model[1] with ancillary routines for calculating elements of final demand, such as personnel consumption and investment. The model is usually used for interindustry forecasting in a peacetime environment. It operates much like most input-output models in that the key element in the model is the table of direct input-output coefficients relating the intersectorial flows of output to the total value of sectorial inputs and other factors used in production. Although these coefficients are derived from intersectorial money flows, they are conventionally considered technological relationships. They express the relative proportions of all inputs used in producing a sector's product.

In INFORUM, the physical amount of input i used in producing a physical unit of good j is defined as a_{ij}. This is the basic building block of an input-output matrix. The other elements are similar coefficients for each sectorial input being used to produce each sectorial product. In INFORUM the table containing the coefficients of all of these intermediate goods relationships, a_{ij}, is called the A matrix. This matrix is predicated upon the conventional assumptions that there are constant returns to scale, and that the underlying technological relationships are not affected by relative price changes. In any given year each a_{ij} is a constant. In addition, INFORUM is a quite refined input-output model in

that each a_{ij} may have a different value in different time periods based on an extrapolation of past trends of inter-sectorial sales.[2]

Similar matrices of coefficients (B, C, and G respectively) that translate final demands for investment goods (b_{ij}), for construction (c_{ij}), and for government (g_{ij}) to sectorial bills of materials have been derived. They are central to calculation of the sectorial impact of final demand from these sources. Total final demand for the i^{th} good, F_i, is derived:

$$(1)\quad F_i = \sum_{j=1}^{90} b_{ij} V_j + \sum_{j=1}^{28} c_{ij} S_j + \sum_{j=1}^{8} g_{ij} G_j + D_i + C_i + E_i$$

Where

- V_j is equipment purchases by industry j
- S_j is construction of type j
- G_j is government non-defense expenditure on category j
- D_i is defense spending on product i
- C_i is personal consumption spending on product i
- E_i is exports of item i

Note that in INFORUM there are 90 different types of equipment, 28 types of construction, and 8 types of governmental non-defense expenditures. Final demand for each type of defense good, D_i, is exogenously specified to the model. C_i, personal consumption, and E_i, Exports, are calculated separately and then fed into INFORUM.

The total final demand for the i^{th} good, F_i, is next added to the sum of all intermediate usage (up to n uses) of

this good. Then, inventory change and imports are taken into account to determine total sectorial output, X_i:

$$(2) \quad X_i = F_i + \sum_{j=1}^{n} a_{ij}X_j + N_i - M_i$$

Where

N_i = inventory change of good i

M_i = imports of good i

Finding total output for all n sectors obviously entails many separate multiplications and additions to determine each final demand use by sector, plus the values for each intermediate product use. First, the B, C, and G matrices are multiplied by the V_j, S_j, and G_j vectors respectively and the additions noted in equation (1) performed for each of the n goods. Then the simultaneous solution of the set of n equations of type (2) can begin. In the typical input-output model this would be a multiplication of the final demand vector, Fi, by the inverse of the A matrix, ($(I-A)^{-1}$ here with dimensions of approximately 200 x 200).[3] Merely to invert this large matrix is a time-consuming task. Moreover, INFORUM derives a different A matrix for each year because relative intersectorial flows are not assumed constant. Consequently, each year's matrix needs to be stored and inverted before the calculations can begin.

Because of the computer core and calculating capacity needed, INFORUM does not calculate sectorial total output, X_i, in this standard way. Instead, the sectorial coefficients in the A matrix are arranged so that products precede their in-

puts as much as possible. For example, motor vehicles are listed before steel and steel precedes iron ore. This arrangement means that the sector selling the greatest proportion to final demand appears first and the sector selling the largest percentage to intermediate use is last on the list. The result of this arrangement of the a_{ij} is to create a matrix with few non-zero entries in the upper right half of its cells, an almost triangular matrix.[4] This allows successive direct calculation of each sector's total output. Thus, after the first sector's intermediate usage, if any, is determined that answer is used to calculate the total output of successive sectors. The general approach to the successive approximations used in these calculations can more rigorously be illustrated with equation (2) excluding M and N. The $(k+1)^{st}$ approximation of the solution is calculated by equation (3):

$$X_i^{k+1} = \left(\sum_{j<i} a_{ij}X_j^{k+1} + \sum_{j>i} a_{ij}X_j^{k} + F_i\right)/(1-a_{ii})$$

This approach is much quicker and costs less than multiplying by the inverse matrix $(I-A)^{-1}$. A perfectly triangular A matrix which allows all intermediate usage values to be determined with one pass through the sectors is not obtainable. However, the one achieved is close enough that two iterations of the initial result produce acceptably accurate totals and still cost much less.

The vector of defense goods, D_i, includes purchases by the Department of Defense, the Atomic Energy Commission (now

in the Energy Department) and the National Aeronautics and Space Administration. It is not calculated within the model because defense spending decisions are judged to not be significantly affected by the economy in a peacetime environment. The exogenous assumption used for Defense in the standard INFORUM forecast (the baseline from which this study proceeds) calls for about one percent real growth per year with virtually no change in the mix of defense goods. Each good's defense final demand (D_i) is, in effect, multiplied by the inverse of the A matrix to calculate its intermediate usage. The sum of intermediate goods and final demand use is the total sectorial output resulting from defense. For convenience, INFORUM has been programmed so that the Defense vector is expressed as a fraction of the 1972 baseline. This makes it relatively easy to scale up the vector.

FOOTNOTES

Chapter I

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4. Charles L. Schultze, "The Economic Content of National Security Policy," Foreign Affairs, April, 1978, p.533.

5. See Emanuel Stein, et. al., Our War Economy, p.27.

6. For a distillation of this view see Schultze, op.cit., p.525. A succinct argument for reducing stockpiles appears in a 1974 letter from Mr. Walter D. Scott of the Office of Management and Budget to the General Accounting Office. U.S. Comptroller General, Stockpile Objectives of Strategic and Critical Materials Should Be Reconsidered Because of Shortages, March 11, 1975, pp. 34-35.

7. George S. Brown, United States Military Posture for FY 1978, p.101.

8. Wood, Marshall K., "PARM - An Economic Programming Model," Management Science, May, 1965, pp. 619-680.

9. For example, see Drew Middleton, Can the United States Win the Next War?, especially the last chapter.

10. For comprehensive treatment of this policy argument and its repercussions see Alan S. Milward, The German Economy at War, London: Athlone Press, 1965. The basic concepts are sketched on page 6.

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1. Marshall, Alfred, Principles of Economics, Guillebaud ed., pages 330, 465, 366, 372, 374, and 377.

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4. Thompson, op.cit., p.23.

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APPENDIX A

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8. See Robert J. Gordon, "$45 Billion of U.S. Private Investment Has Been Mislaid," American Economic Review, June, 1969, particularly pages 225-226.

APPENDIX B

1. The model is open in that some elements of final demand are exogenously specified. For example, interest rates, tax credits, and defense spending are not calculated in the model. For an overview of INFORUM see Almon, et. al., op. cit., pp. 1-21.

2. For more detail on the nature of these extrapolations see Almon, et. al., op. cit., pp. 157-165. The discussion in this study, and in this Appendix especially, follows the conventions used by Almon, particularly in Chapter 8.

3. Each coefficient in the inverse matrix is the proportional relationship of a sector's total output to that sector's final demand, i.e., the units of direct and indirect output per unit of that sector's final product use. Using a simplified version of equation (2) which ignore imports and inventories this may be clarified as follows:

$$X = F + a_{ij} X$$
$$X - a_{ij}X = F$$
$$X(1-a_{ij}) = F$$
$$X = \frac{F}{1-a_{ij}}$$

Each inverse matrix coefficient thus is $\frac{1}{1-a_{ij}}$

4. For a stylized example of such a matrix, see Almon, et. al., op. cit., p. 149. This same sort of triangular matrix approach also has been used in past preparedness planning efforts. An example can be found in the Program Analysis for Resource Management (PARM) model developed in the early 1960s to help assess national ability to recover from a nuclear attack. See Marshall K. Wood, "PARM - An Economic Programming Model", Management Science, May, 1965, pp. 642-650.

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